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The first photograph of a tactical atomic bomb exploding. This test explosion took place in Nevada during the first week in November; it was the 21st test in the series which began with the very first atomic bomb burst—in July 1945

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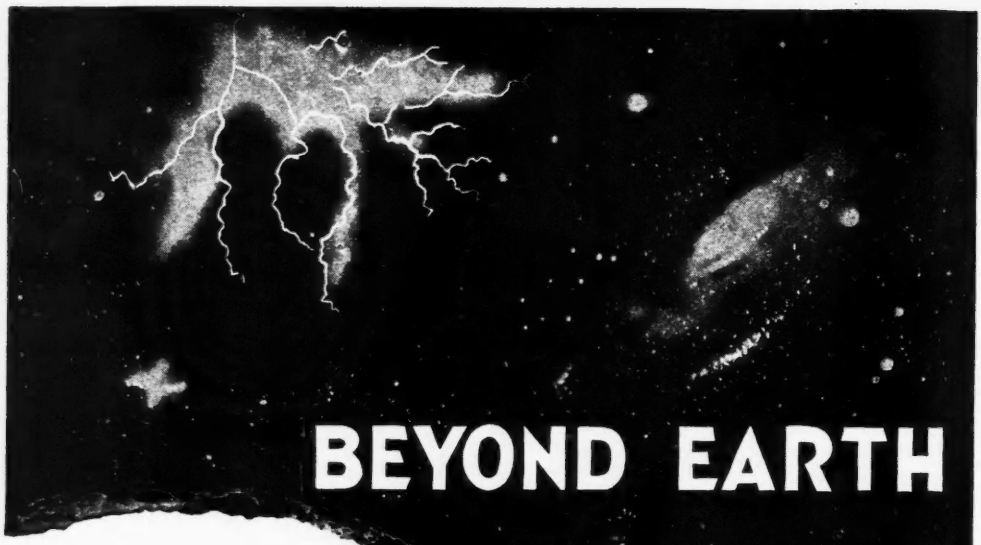

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DISCOVERY

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The Progress of Science

A Sociologist Studies Scientists

ONE of the most interesting articles we have read for a long time appeared in a recent issue of the *Bulletin of the Atomic Scientists* (Vol. 7, No. 6) and was entitled "The Origins of the Scientific Species." The author, Prof. Richard Meier, who belongs to the University of Chicago, attempts to give a sociologist's interpretation of the typical political, social and cultural orientations of the different kinds of scientists —chemists, physicists, biologists and so on. The article is based on discussions Prof. Meier had with over a thousand scientists from all over the United States, and it sheds a revealing light on various sorts of interactions which occur between a society and its science.

At the outset the author provides a sketch of the social conditions which led to the development whereby university education became available to every student "with grit and determination". The era of Sinclair Lewis's *Main Street*, *Dodsworth* and *Arrowsmith* was one of rapid urbanisation and it was accompanied by a decline of the rural community and the recognition that henceforth the path to higher social status and economic security led through the colleges and universities to the professions and managerial posts. The smaller universities and the country colleges doubled and redoubled their intake, so that the eventual result was that university education was open to all intelligent students. The student body came to have a remarkably constant character and very few differences can be found between the undergraduate community of one university and the next; as Prof. Meier says, "Any institution with tuition fees low enough to permit a fellow with grit and determination to work his way through college obtained a fair cross-section of the bright youngsters of the period." He states that student bodies ranging west from Pennsylvania and North Carolina developed remarkably similar social environments; the one region which did not conform to the general pattern was New York City, and this difference was due to the big concentration of new immigrants.

After thus setting the social scene, Prof. Meier proceeds to consider the various scientific professions one by one. The biggest of these, numerically, is the chemical profession. Prof. Meier found that chemists mainly came from middle-class families, being the sons of schoolmasters, small businessmen and farmers, for instance. In their youth they were encouraged to read widely, though the kinds of books they had access to were limited because they lived in communities typified by that described by Sinclair Lewis in *Main Street*. He thinks that popular books with titles such as *The Romance of Modern Chemistry*, which were available in the local libraries and the school libraries of the period and which presented chemistry as something novel and romantic and offering a promise of release from the tedium of life in a small town, influenced their choice of career. Another deciding factor may have been the fact that chemists were less affected by the prevalent unemployment and could get jobs when other graduates were failing to do so, but Prof. Meier doubts whether this could have had much influence as only a few students would have been aware of this factor at the time they decided to study chemistry. During the period between the two World Wars, half of the science undergraduates took up chemistry as their main subject. The best students went on to become professional chemical engineers or chemists. There was a tendency for the students who could not cope with physical chemistry and "who could not comprehend thermodynamics" to drift into biochemistry, bacteriology, ceramics, and such branches of chemistry. The result was that postgraduate chemistry received far more than its fair share of what Prof. Meier calls "the higher competences and rare intellects", a fact which is reflected today in the thickness and quality of the American journals of chemical research and the vigour of chemical technology. In political matters Prof. Meier finds chemists are seldom rebels or radicals, and he considers that they are equally well adjusted in relation to their fellow workers; "in an organisation they grumble extensively but still are responsible, patient and co-operative", he comments. Prof. Meier concludes that chemists represent the largest single reservoir of managerial talent in the technological area, and he predicts that these capacities will be exploited even more in years to come, both by industrial corporations and by government agencies.

Physicists tend to come from the upper middle-class and the intelligentsia, according to Prof. Meier. Great numbers,

he discovered, are the "sons of ministers, rabbis, deacons, cantors and other church stalwarts". Their homes provided a wealth of ideas and plenty of books and an atmosphere of "idealism, ethical behaviour and rationalised morality". A youthful capacity to handle mathematical abstractions with ease Prof. Meier evidently considers to be an all-important sign that a student may have the kind of brain that physics requires. Before the mid 1930's there were only about twelve significant physics departments in American universities, but the situation changed quickly, partly as a result of the entry into the United States of many brilliant physicists from Nazi Germany. The result, as Prof. Meier puts it, is that the bulk of American physicists were "still absurdly young when the war directed their activities into two large-scale efforts—electronic devices, including radar, and the atomic bomb. Physicists, Prof. Meier finds, tend to be radicals in their political thinking. He links this to the fact that the physicist more than any other scientist deals with abstractions which make nonsense out of observations based upon the commonplace; he is educated in doubt and can disregard evidence which to the ordinary observer is both convincing and conclusive, Prof. Meier goes on to remark, "Thus many physicists choose a vague leftist political philosophy, partly as the only relatively rational set of value premises which was offered at the time (1938–40) in the world of ideas."

He has a few words to say about the fact that the most disillusioned scientists are to be found in the ranks of physicists. His comment here is as follows: "The developments of the last decade brought on many value conflicts within the minds of physicists which have often resulted in an apparent change of personality. No one hates secrecy with as much emotional vigour as a physicist, yet hardly any are more thoroughly afflicted with it. Everyone knows the disillusionment that accompanied the lack of international agreement on atomic energy but few can imagine the confusion of thought, the loss of goals, and even faith, that followed it. For many the fun has gone out of physics, they feel stale and unproductive."

The biologists, says Prof. Meier, are a mixed bag, because the profession of biology represents the confluence of several quite different streams of talent. First there are those who graduated in chemistry but who did not enjoy physical chemistry and therefore "moved into areas where their laboratory techniques were welcomed and the theory was less abstract." Such biologists had their origins almost entirely in the lower middle and professional classes.

The second group of biologists, says Prof. Meier, is made up of exceptional minds which developed in agricultural surroundings. Any bent they had for experimentation when they were children had to be satisfied with the material available on a farm and rather naturally they turned to plants and animals. In the interwar period the number of such students who went to the university to study biology dwindled, Prof. Meier suggests because of the growing intrusion of urban values into the countryside. By 1940 it was mainly the southern states of America which contributed substantial numbers to this stream. Prof. Meier states that a large proportion of the senior biologists in America had such origins.

The third group of biologists, and according to Prof. Meier this is the largest group, aspired to become doctors but were disappointed. (Almost the reverse has been true in Britain, though the establishing of the National Health Service, with its relatively high rewards for doctors and dentists, may alter the opinion of British youth when it has to assess the relative satisfactions offered by a career in biological science as compared with a career in medicine.) The American biologists who would rather have been doctors fall into two categories; the first consists of the sons of poor families which could not afford the fees to put them through medical school; the second category consists of middle-class types who were unable to pass the entrance examination for medical school.

Of the political views held by biologists, Prof. Meier says: "One doesn't think of this group as having any political orientation, yet I have often been surprised to detect attitudes voiced which hark back to LaFollette progressivism and quite radical-sounding ideas which were discussed widely in the farm areas in the days of William Jennings Bryan. Other than these few minor deviations, they seem to conform quite closely to the Protestant ethic."

Prof. Meier has collected some data which sheds a little light on the artistic tastes of scientists. Physicists, he discovered, show a strong preference for the music of Bach, a preference which incidentally seems to be common among physicists regardless of their country of origin. (Some people have expressed the opinion that physicists and mathematicians tend to concentrate on the developing pattern of notes, in the same sort of way that they can see readily the pattern in a series of numbers, such as a geometrical progression, and so they tend to find that a strong melody line interferes with their enjoyment: which may help to give meaning to Prof. Meier's sly parenthesis, "I'm told that some *experimental* physicists will go so 'modern' as to embrace Beethoven." Incidentally several composers, including Benjamin Britten, showed remarkable mathematical talent when they were young.)

Among chemists classical music is popular, but they seem to want melody and colour rather than counterpoint; Brahms, Tchaikowsky, Enescu and Ferde Grafe are typical of the composers chemists favour. Prof. Meier finds physicists are generally sensitive to art, and adds that "art criticism among circles of physicists and their wives is perhaps as sophisticated as one finds anywhere in the United States". Chemists, on the other hand, are summed up as being "definitely middle-brow" not only in their choice of music, but also in their artistic sensibilities and their tastes in domestic furnishings. But Prof. Meier makes it quite clear that 'middle-brow' is a pretty vague sociological term in so far as "it brings together everyone from *Collier's* readers to *New Yorker* enthusiasts (where a merging occurs with the 'high-brows'.) He believes that for the vast majority of scientists the aesthetic sensibilities were already moulded by the time they entered college, and since then there has been only minor adaptation, just as the foundations for their political orientations had also already been laid.

One of the most interesting passages in this article deals with the "drifters and hybrids" who switch from one branch of science to another. According to Prof. Meier the switch is nearly always from "a more precise subject to a new area which is less precise in its data-gathering and experimental techniques." He defines the 'drifter' as a

person who came to realise that he had chosen an unsuitable profession while still obtaining his training. "These men found, to their inner consternation, that there were fields more intellectually exciting than their own. America's cafeteria-style education system made it quite possible to salvage most of the effort already invested, so the change of direction was not a formidable undertaking. By this process the armchair sciences, such as theoretical chemistry, physics, and mathematics were greatly enriched from the ranks of the engineers and the applied science areas. There were much larger numbers of incompetents and dilettantes also drifting at the time, but very few of them are identified as scientists today; therefore they can be excluded. The drifters were outstanding among youngsters who were all exceptionally able. They found it easy to discover the standards of behaviour in the new profession and adjusted without great difficulty; however, one could always note a more practical bent in their line of theorising than was common among their colleagues."

The hybrid scientist is a somewhat rarer phenomenon, says Prof. Meier. "He is the fullfledged professional who decided that the problems were more vital in some area for which he had no training whatsoever. Crossing over at this late stage takes fortitude because the more solid members of the profession he has been in and those in the new area will mutually cluck their tongues at his rashness. Yet there have now been so many instances in which crossing over has been accomplished successfully that the research councils and foundations have been setting up funds and programmes to encourage still more of this sort of thing. Thus physicists may move into metallurgy or meteorology, engineers into psychology, and biology is fair game for everyone. Even the social sciences are receiving a few. The contributions of the hybrids are very rapidly bringing about a unification of the conceptual framework of the various scientific disciplines."

The hybrid scientist is very important, for he develops the whole of science by bridging the gap that separates different areas of science, as for instance Gowland Hopkins did when he linked biology with chemistry and started the subject which we now call biochemistry. To quote Prof. Meier, "When the solution to the problem takes him to the boundary of his established competence, he refuses to be intimidated. Armed with the concepts and techniques he has learned and the special insights he has personally deduced, he will vault the barrier—if the new subject matter is more diffuse and qualitative."

Finally Prof. Meier considers some of the ethical problems involved in a scientific career. He holds that "Scientists are bedeviled because two codes of behaviour are demanded of them, and society requires that these be kept separate. In the laboratory and design office an attempt is made to exclude emotional bias and moral standards (mainly because experience tells us they lead to errors in logic and fact-finding), while in the remainder of daily life a rigorous scientific outlook is quite reprehensible. The mark of the successful scientist is that he has disciplined himself to compartmentalise his life so that neither side will seriously influence the other. It is not surprising then that many have developed schizoid personalities and that they suffer from the mental strain that is thereby induced." The scientist's biggest difficulties will arise if his work is concerned with something like weapon development. Here his scientific and his social ideals tend to "gang up" on him, and a satisfactory solution of this ethical problem may depend largely on some quite simple faith, such as a belief in duty. "The most sensitive [scientists], of course, do not take risks with their consciences and refuse to join up, but the letting of research and design contracts to existing industrial organisations and academic research institutes means that the issue can be brought right to the scientist in his own laboratory. He must either accede or move out. Knowledge of this destructive aim seldom perturbs the engineer, since cause-and-effect relationships in society and international relations are extremely vague to him. Most of the chemists can effect the compromise without visible qualms, but the physicists are made very uneasy. The latter build up highly elaborated rationalisations to justify what they do but are obviously not confident of the logical validity of their alibis. The dilemma of what to do about

The Discovery of 1951

A READER has sent us the following cutting from the *Sunday Dispatch* of October 28, 1951, and asks whether we have published anything about the giant flowers it mentioned:

> *A chemical sometimes used for treating gout [colchicine] has enabled a firm of gardeners of Leicester to raise a race of giant flowers—hollyhocks with blooms the size of dinner plates, marigolds like yellow saucers, and antirrhinums as big as apples. Next year the public will be able to buy seed that will produce a 3-ft. tall snapdragon with a 'frilly' edge—the first of the monster plants to be on sale.*

This cutting we found interesting for two separate reasons; firstly, because we had already grown some giant tetraploid antirrhinums from seed bought from the Leicester firm of Harrisons in *March* 1951, and secondly, because in the June 1951 issue of DISCOVERY we published the following item in "Far and Near".

> *New tetraploid varieties of flowers are conspicuous in this year's seed catalogues. For instance, Burpee's of Clinton, Iowa, list several tetraploid antirrhinums. These were created from diploid forms by colchicine treatment, and possess* twice *the normal number of chromosomes. The tetraploid snapdragons are exceptionally strong, and their blooms extremely large; moreover, many of the flowers are attractively ruffled; the central flower spikes grow 2 ft. and more in height. In the Burpee catalogue there are listed white and pink tetraploids, as well as the Sunset hybrids which range in colour from primrose-yellow flushed pink to rosy bronze. The English firm, Harrisons of Leicester, list the new tetraploid snapdragons. Tetraploid annual phlox, which originated by colchicine-treatment of selected diploid specimens, is also catalogued by Burpee.*

the uses to which their findings are put confronts all the scientific species today, but each approaches the issue in a different manner. The engineer does not take the trouble to comprehend it, the chemist is more likely to be the 'realist', explaining he couldn't do much about it unless chemists were the rulers, while the physicist sulks and worries, occasionally bursting into a protest. Few biologists have been personally affected as yet (the fraction involved in biological warfare was very small) because their efforts are directed to the betterment of health and the improvement of agriculture—goals which can still be both practical and idealistic. The fact that only biology offers the same ideals that all science did in H. G. Wells's time is another important reason (operating at the sub-conscious level) for the current drift of the best scientific minds into biological subjects."

Professor Meier points out that within any nation the chemists will disagree with physicists, who will disagree with the biologists, when discussion turns to the question of what a scientist's duty should be. But he adds that the coming generation will start from quite different social premises and it may be able to effect a compromise between these two disparate worlds. Present-day students, he says, view a scientific career as a path to social prestige and security; they are less affected by the idea that it is a road to romance and to the power which controls the forces of nature, and he adds this comment: "*The new generation doesn't care to 'set the world on fire'. Like fire, they see science and engineering as double-edged occupations which may result in either good or evil. They hope to earn a decent income with intellectual effort and to live out a normal existence; they expect trouble but do not intend to be responsible for stirring it up.*"

Prof. Meier's observations apply to America, and some of them may not apply to Britain. It would certainly be worth making a similar study in this country, and it would be good exercise for a team of British sociologists who tend to tackle problems of such simplicity that they get little chance of developing new techniques of investigation. It will also serve to bring the sociologists in contact with the natural sciences, from which they might well be able to learn scientific methods applicable to sociology.

Lord Cherwell's Return to Power

WITH the return of Churchill to No. 10 Downing Street, Lord Cherwell has returned to power. As Paymaster-General he now has a seat in the Cabinet, and he has been given special charge of atomic developments.

For nearly a quarter of a century Cherwell has been advising Churchill on scientific questions. Readers must have noticed that Churchill's remarks about science are generally well-informed, shrewd and to the point. This is a clear sign that he receives sound advice on matters scientific, and that he accepts it. Nearly all that advice comes to him direct from Lord Cherwell. To quote Churchill's own words from *Their Finest Hour* (Vol. II, *The Second World War*, 1949) Cherwell has been "my trusted friend and confidant of twenty years."

In the last war he organised the Prime Minister's Statistical Branch—the "S" Branch of Churchill's war memoirs—and this compact and highly efficient intelligence unit kept tabs on all aspects of the war effort, both civilian and military. It was also highly successful at keeping tabs on the statistical branches of all the various ministries. In several instances the key men in departmental intelligence units were ex-students of his; this was so at the Air Ministry, for example, where the Deputy Director of Intelligence Research was Dr. R. V. Jones, who came from the Clarendon Laboratory. Cherwell's particular genius lies in scientific intelligence—the term is used in the same sense as one speaks of "military intelligence". As Churchill has expressed it, he "could decipher the signals from the experts on the far horizons and explain to me in lucid, homely terms what the issues were. Anyone in my position would have been ruined if he had attempted to dive into depths which not even a lifetime of study could plumb. What I had to grasp were the practical results, and just as Lindemann gave me his view for all it was worth in this field, so I made sure by turning over my power-relay that some at least of these terrible and incomprehensible truths emerged in executive decisions."

In Cherwell's special competence for accurately summing up a situation in such a way that immediate action could result from his clear-cut advice Churchill had unbounding confidence. This fact is revealed by a typical minute from Churchill to Cherwell which reads as follows: "Let me have on one sheet of paper a statement about the tanks. How many have we got with the Army? How many of each kind are being made each month? How many are there with the manufacturers? What are the forecasts? What are the plans for heavier tanks?"

There can be but little doubt but that Churchill relied on Cherwell's advice in preference to that of other scientists, because Cherwell could sum up a critical situation, which demanded immediate action, on a single sheet of paper, whereas others, motivated by too strong a sense of caution, would produce unwieldy memoranda running to many thousands of words and framed in such a way that only an expert could draw any useful conclusion from them.

In the process of editing DISCOVERY we have been forced to listen to may criticisms made by scientists about Lord Cherwell, but in every instance their comments betrayed a certain jealousy which arose from the fact that they resented the power and influence that Lord Cherwell wields. It cannot be denied that Lord Cherwell has long been the most powerful man of science in this country, but this fact should occasion the reverse of regret, for Lord Cherwell is eminently fitted to fill a position of power. Not the least of his qualifications is his awareness of the responsibilities which attach to such a position.

Lord Cherwell will have plenty of scope to exercise his special talents in the coming months. Britain's atomic energy project has muddled itself into the doldrums, and as the dead hand of the bureaucrats is one of the main factors depressing our atomic efforts it is to be hoped that he will go into action on this front without delay. His speech to the House of Lords this July (*see* DISCOVERY, August, 1951, p. 235), shows that he is thoroughly aware of all that is wrong at Harwell and at the other atomic establishments, and his appointment, which will give him an office at No. 11 Downing Street, means that Churchill agrees with Lord Cherwell's opinion that atomic energy developments are so important to the country that the

member of the Government who holds the highest administrative responsibility for these activities should have direct access to the Prime Minister and the Cabinet.

Another matter which calls for prompt investigation and swift action is the problem of improving technological training. With the change of government, the Ministry of Education has probably been forced to realise that the proposals contained in the White Paper, which we criticised in our last issue, are not good enough, and that this problem will have to be tackled from a different angle. We understand that the Tories favour the idea of setting up two technological institutions on the lines of M.I.T. or 'Caltech', and there can be no doubt that the sooner a start can be made on this project the sooner we can hope to see the industrial and economic benefits which will inevitably follow an improvement of the technological component in the British industrial effort.

A New Atomic Epoch is Beginning

READING between the lines, it is possible to see from the latest half-yearly report of the U.S. Atomic Energy Commission that America has leapt so far ahead since 1945 that she has entered into a new epoch of the Atomic Age. She has done so ahead of all the other countries, which have the requisite scientific and technological skills and the industrial capacity and are therefore making similar progress in the development of atomic-energy projects.

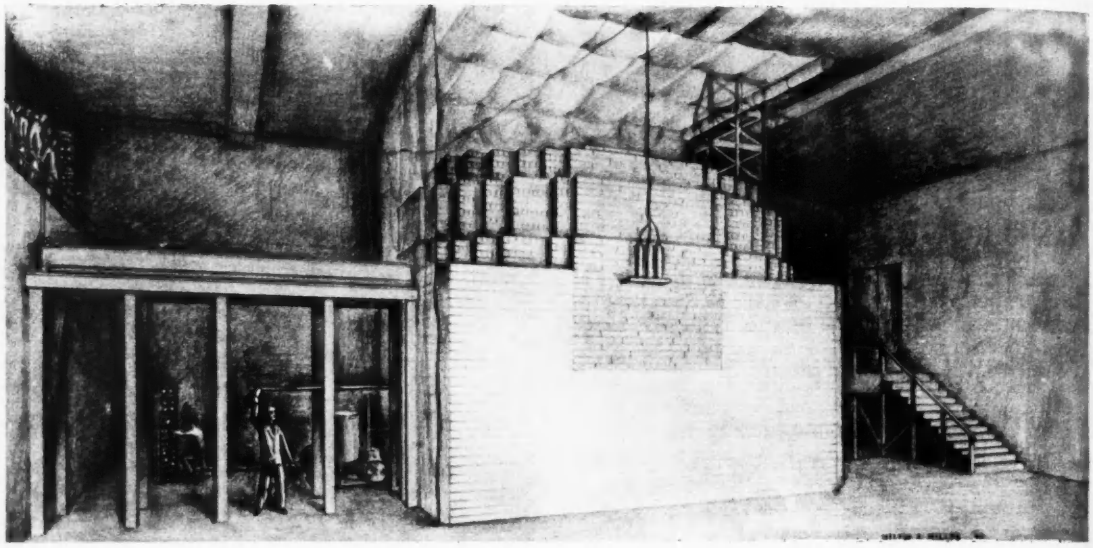
An article in *Chemical Engineering* (August 1951, pp. 114–17) contains a first-hand account of America's major atomic installations and provides a good impression of the scale on which development work is proceeding. Development of an idea is rarely less difficult than the task of collecting the basic scientific details on which that idea is based, and this is well illustrated by the story of the American plutonium plant, which forms part of the Hanford Engineer Works at Richmond. (It was this plant which turned out the plutonium which went into one of the two atomic bombs dropped on Japan in 1945.) The plutonium process had been thought to be far more adaptable to large-scale production than the method of U 235 separation by gaseous diffusion, and for that reason two more reactors to transmute uranium into plutonium were built in the Hanford Works. But operating difficulties did arise, mainly in the chemical plant which treats the material from the reactors and concentrates the plutonium that material contains. These difficulties upset the production schedule considerably, and it was not until 1950 that the anticipated increase in the plutonium output of the Hanford Works began to materialise. But the chemical engineers have now solved most of the problems involved in the large-scale handling of the radioactive materials which leave the atomic piles, and the increased plutonium output has now been achieved—and at lower costs. The development programme had to be altered when the decision was made to attempt the production of a hydrogen bomb, and this has led to a concentration of effort on a dual-purpose plant which can make either plutonium or tritium. (Tritium is prepared from lithium in reactors of the same type as those used to make plutonium from uranium 238.) This dual-purpose plant is being built by the chemical firm of Du Pont on the Savannah River in S. Carolina, and is due to begin production in 1954. Its cost will be about 1000 million dollars.

Lord Cherwell, the new Paymaster-General, who has been given the responsibility of supervising atomic energy research and development, photographed as he left the first Cabinet meeting to be held after the election of the new Parliament.

According to the article in *Chemical Engineering*, the Savannah River reactors will differ radically from the Hanford reactors. Designers now favour atomic piles using heavy water instead of graphite as the moderator. Such heavy-water piles are considered more versatile and convenient. The essence of such a reactor is a huge shielded tank containing heavy water in which is suspended a lattice of natural uranium slugs. The heavy water serves two functions—it acts as a moderator for the neutrons released in nuclear fission, and it can be circulated through a heat exchanger to dissipate the hundreds of kilowatts of energy which are released.

At the Hanford Works elaborate equipment had to be installed in order to cool the reactors; the cooling process involves taking water from the Columbia River, purifying it, circulating it through the cooling channels, then storing it for a time so that its radioactive constituents can decay, and finally returning to it the river. This equipment is necessarily elaborate because it has to fulfil so many functions. The process of cooling a heavy-water reactor is much simpler, and does not require the elaborate equipment inseparable from graphite reactors.

A second advantage obtained with a heavy-water pile arises from the fact that the nuclear 'fuel' elements can be changed without having to stop and rebuild the whole pile.

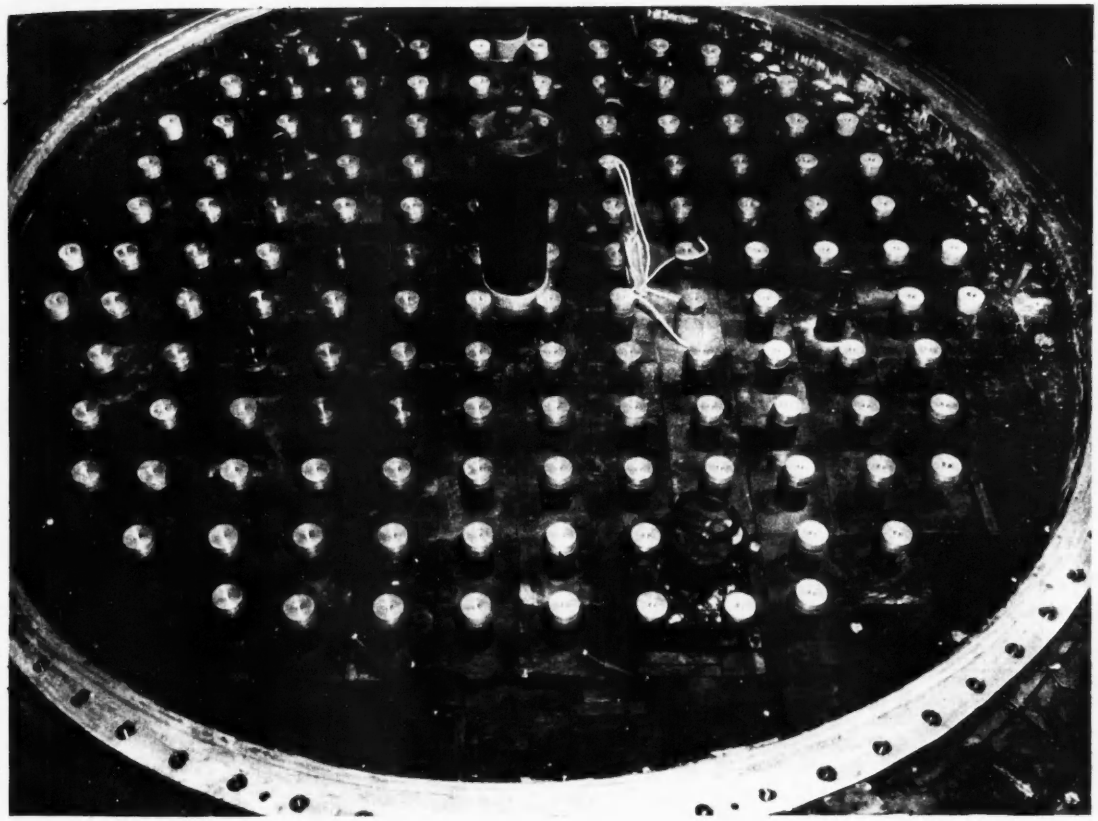


Just nine years ago—on December 2, 1942, to be exact—the first atomic pile, built of graphite blocks and uranium slugs, was brought into operation for the first time, so proving the practicability of a self-sustaining chain reaction. This is the only photograph ever taken of that pile; the reactive part was roughly spherical, as is indicated by the circular outline of the nineteenth of its layers of graphite bricks. Another thirty-seven layers brought the pile to critical size. The sketch at the top of this page shows the external features of this pile in its original home—a squash court belonging to Chicago University.

To change over from plutonium to tritium production, all that is necessary is to get the pile running on slugs of enriched uranium, and then to insert as much lithium metal as the pile can hold without the chain reaction being stifled. Lithium consists of two isotopes, mixed in the ratio of nine parts of heavy isotope to one part of light isotope. In the pile the neutrons select the light lithium nuclei, splitting them into helium and tritium; the other isotope remains virtually unchanged.

During the war heavy water could not be used because it was not available in quantity. Today, Canada is able to supply plenty of heavy water, and the U.S. Atomic Energy Commission is planning to make more. It is almost certain that the reactors in the new Savannah River plant will be cooled by heavy water. This will mean the saving of the million or more kilowatts of power, which at the Hanford Works continue to be wasted in warming the Columbia River!

The gaseous-diffusion process for concentrating U 235 was miraculously successful right from the start, when it was first put into operation at Oak Ridge in 1945. This is a remarkable fact when one thinks about the delicacy with which pressures, temperatures, and other factors need to be controlled in this process, but it is just another example of the many successes to the credit of the men who design automatic-control systems. An industrial firm, Union Carbide, operates the gaseous diffusion con-plant, and has continually improved the trol equipment to the stage when the plant is now almost a perfect industrial robot.



Their convenience and versatility have brought heavy-water piles into favour. The essence of this sort of pile is a shielded tank containing heavy water in which is suspended a lattice constructed of natural uranium slugs. This picture shows the heavy-water pile at the A.E.C. Argonne National Laboratory, Chicago. The shield has been removed to disclose the end of the uranium slugs; in the centre is seen the 'thimble', which extends nearly to the bottom of the tank. Materials to be subjected to the radiation inside the pile and thus rendered radioactive are inserted into this thimble.

U 235 production was expected to become obsolete when plutonium production got into its stride, but this view was revised after the 1948 bomb tests at Eniwetok which suggested that the military demand for U 235 would continue. As a result, U 235 production at Oak Ridge has been expanded. A further, and very much larger, expansion was organised after it was known that the Russians had exploded their first atomic bomb. These two additions mean that Oak Ridge will soon have a capacity twice what it had in 1945.

A second Oak Ridge is being constructed at Paducah, with U 235 capacity equal to that of Oak Ridge itself after the two expansions of production have been completed.

In America today the prospect that atomic piles will soon be adding to the country's power resources grows brighter. At the present time, of course, the operation of the atomic pile actually *subtracts* a vast quantity of power—indeed the Atomic Energy Commission is the largest single *consumer* of electric power in the U.S.A., which shows how long a time must elapse before atomic power is fully ready to replace other sources of power. One experiment which is likely to arouse great interest will be the reactor at the Arco Proving Ground in Idaho. This has been designed to test the practicability of breeding nuclear fuel, and it is intended to run this pile at such a power that it produces steam capable of driving a 1000-kilowatt generator.

Once the Atomic Energy Commission starts generating electric power in substantial quantities the whole economic picture presented by the workings of the Commission will begin to change, for then it will be able to use the power generated in A.E.C. plants, and so cut down the bill for the power it has to buy from outside. As this article suggests, it will shortly become possible for the A.E.C. to think in terms of generating its own power at a capital cost of 40 dollars per kilowatt—and the fuel for the generators would cost nothing at all!

Winds, Currents and Fisheries

Prof. C. M. YONGE, F.R.S.
Dept. of Zoology, Glasgow University.

FISHERMEN gain their livelihood by hunting animals, and they work at the disadvantage of rarely being able to see their quarry. Only the light of experience illuminates the depths into which they lower their nets or lines. They have to reconcile themselves to meeting good fortune one day and bad fortune the next, and they must accept the luck of the chase as all hunters must. They know that fish are mobile and also that they are often irregularly distributed, for some reason or other. But if the total stock of fish falls below a certain level then time, labour and money are wasted in vain attempts to catch them in adequate numbers.

Undoubtedly stocks of edible fish do alter. A major reason, and particularly on the nearer fishing grounds, is over-fishing, for which the remedy lies in international control both of fishing methods and of fishing intensity; what man has caused he *can*, if collectively he *will*, prevent. Quite apart, however, from the effects of fishing, the populations of many species of edible fishes—herring and haddock, for instance—alter greatly from year to year. Fish distribution may also change radically over a long period of time; thus fish may desert areas where once they were abundant. Within historic times the herring, for instance, has retreated in the Baltic. On the other hand a species of fish may extend further afield, like the cod, which in this century has moved further northward, accompanying the spread of slightly warming bottom waters into arctic seas.

We cannot hope to control these major fluctuations in the numbers and distribution of fishes. But it is worth trying to discover their underlying causes. This knowledge is needed before one can attempt to assess with accuracy both the quantity and the general distribution of food fishes in any particular year. Accurate prediction would make an enormous difference to the efficiency of fishing, for modern fishing vessels, even the smallest, are costly to build and to maintain, and they must catch fish quickly and in quantity if they are to return a reasonable profit on catches marketed at reasonable prices.

Unlike scientific research in agriculture, much of which is obviously concerned with livestock and crop improvement, and pest control, the results of fishery research have seldom had such obvious bearing on the immediate problems which face commercial fisheries. It could hardly have been otherwise, with so much to learn in this field which is both wide and obscure. The Norwegians made a notable advance when they discovered how to determine the age of herring by the rings on the scales. It was already known that herring stocks differ greatly from year to year, but the use of the Norwegians' technique made it possible to study the fluctuating herring population in more detail. It was discovered that the herring stocks are composed of individuals from several different age-groups and that the proportions of a herring population which belong to a particular age-group vary erratically. The age composition of a herring population proved to be no simple matter; it was not simply a case of the youngest fish being the most abundant, and the numbers in the older age groups diminishing progressively as the age of the group increased. Instead, it was shown that a herring population could be almost entirely composed of fish belonging to one or two particular age groups—such groups came to be known as *good year classes*. The recruitment of young fish in other, less favourable, years was often almost negligible. Similar results were obtained when other food fishes were studied.

Such knowledge of the composition of the herring shoals made it possible to attempt forecasts of future yield. For a number of years now, forecasts have been made each year of the quantity of herring likely to come to the fishing grounds off East Anglia in the autumn. Herring are pelagic fishes which move freely through mid- and surface-waters, and they may be deflected from their usual course by abnormal water movements or winds or, perhaps most often, by dense and widely stretching patches of microscopic plant life—notably by the planktonic diatom, *Rhizosolenia styliformis*. So the forecasts can never be more than provisional, although there are years when, at best, only a few fish can be expected. With the haddock, a bottom-living fish, analysis of the age composition of the population provides a more certain basis of estimating the success of the commercial fishery in the following year.

It was, however, difficult to decide which particular factor (or factors) were controlling the size of the annual addition of young fish to the stocks. If the figure for the new brood hatched in a particular year was low, what was the reason: had the parent population failed to spawn, had food been lacking for the young fish, had the young fish died without reaching mature form and habit? These and many other possibilities were debated. Now at last some indication of the answer seems to be coming. By a nice combination of the ideas and labours of Dr. J. N. Carruthers and his colleagues of the Hydrographic Department of the Admiralty with those of workers at Hamburg and at Aberdeen, evidence is presented that the decisive factor may be wind.

Wind Effect on Brood Survival

So far as the haddock is concerned, once the young fish have reached the bottom they have a good expectation of life, at any rate until they are large enough to be caught in the trawl. The adults also appear to spawn in adequate numbers each year. So it seems that the risk of mass destruction must arise in the intervening period, that is, during the time the newly hatched larval fishes are living in the surface waters and are feeding upon plankton. Then they are at the mercy of surface drifts caused by winds.

Haddock live within the great eddy system in the northern North Sea (Fig. 1). Deductions of wind direction based on records of barometric pressure over this and surrounding areas suggest that the years when the haddock brood failed were those in which the surface waters would have been driven in northerly and north-easterly directions.

The still passive young fish would then have been carried away from their feeding grounds to meet inevitable destruction in north-flowing currents along the coast of Norway. On the other hand, winds moving in the opposite directions could keep the young fish and their planktonic food together in the waters of the North Sea; the temperature there would remain favourable for their development, and the young fish would be in a good location when eventually they settled down to the bottom of the sea and took up residence there. This explanation, if confirmed by careful future observations of wind direction and brood survival, will permit the stocks of commercial fish to be estimated *two years ahead* instead of one year as is possible at present.

With at least some races of herring the young seem as much at the mercy of wind-generated drift as are young haddock.

Suggestions of widespread mortality in the clean waters of the open sea may perhaps appear somewhat far-fetched. We live on land, where the temperature, for instance, can change more in the course of one single day than it does in the sea in a whole year. Moreover, we can control our body temperature, so that temperature changes in the surrounding air hardly affect us. It is not at all easy for us to realise how vastly different life must be for the cold-blooded animals that dwell in the sea. What seem to us the most insignificant of differences between the physical or chemical properties of two bodies of water represent to fish the differences between two very different environments. The animal populations of these bodies of water may be as different as the fauna of moorland and the fauna of an adjacent forest.

FIG. 1. Map showing currents in the northern North Sea including the eddy system. H marks the centre of haddock distribution. STIPPLED AREA shows the distribution of the planktonic arrow worm, *Sagitta elegans*, which is an indicator of mixed oceanic and coastal waters. C, the position where water collected from Celtic Sea. E, Eddystone, off Plymouth, where the water is coastal, containing the indicator species *Sagitta setosa*.
(Modified after Russell).

During the past quarter of a century there has been a marked change in the nature of the sea water which occupies the western end of the English Channel. It is now significantly poorer in nutrient salts than it used to be, while there has been a notable alteration in the abundance, and more particularly the nature, of the planktonic life. Mr. F. S. Russell, the director of the Plymouth Laboratory, was able to show how one species of planktonic arrow worm, called *Sagitta elegans*, that used to inhabit the waters off Plymouth, was replaced by another species called *Sagitta setosa*. He was able to associate the first species with water of mixed oceanic and coastal origin, and the second with poorer and exclusively coastal waters. Yet another species, called *Sagitta serratodentata*, he found to be characteristic of the pure oceanic water off the west of the continental shelf.

Use of Biological Indicators

These three species of *Sagitta*, together with others which occur only in certain waters, are now known as biological indicators providing evidence of the nature of the waters they inhabit as valid as that provided by the delicate—and laborious—analysis of their chemical and physical properties.

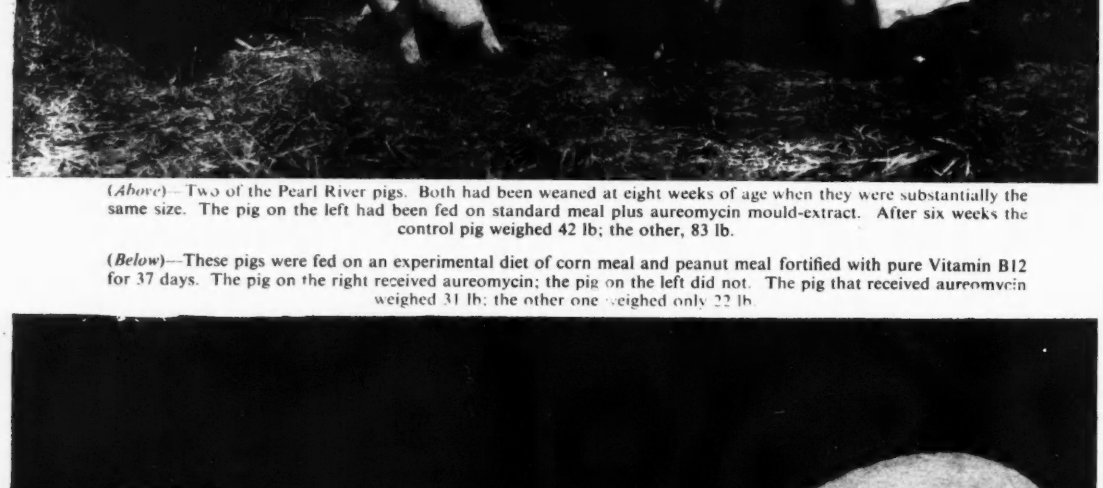
When the chemically richer water flowed in from the Atlantic the plankton was more abundant than it is today, as well as different in character, while spawning herring formed a valuable fishery in Bigbury Bay, near Plymouth. These fish no longer appear in that bay. In further confirmation of the change in waters that has occurred, a series of most interesting experiments has recently been conducted in the Plymouth Laboratory.

Samples of water have been collected from near the Eddystone, off Plymouth, and again from the Celtic Sea and from the areas of water to the west of the Scilly Isles and south of Ireland (Fig. 2). On the sure evidence provided by the presence of the indicator species, the former proves to be coastal water, whereas the latter is mixed oceanic and coastal, and is the richer in nutrient salts. In these two samples of clean water taken from the open sea, Dr. D. P. Wilson has attempted to rear the eggs and young of certain kinds of sea urchins and worms. He found that development was normal in the distant samples, and abnormal or unhealthy in those from the Eddystone. He concludes that the coastal water from the Channel, as well as being poorer in nutrient salts, must lack some substance essential for the development of these particular species.

There is nothing to indicate at present what is the nature of this missing substance. Time will doubtless reveal this but for the time being we are left with a striking additional demonstration of the intricacy of the marine environment. Adjacent waters are shown to differ widely in the quantity and quality of the life that can exist within them. When planktonic fish are driven by winds from one environment to another they suffer mass destruction. When the boundaries of the water masses themselves move, as they have been shown so certainly to do, they bring fertility or withdraw it from wide areas.

(*Above*)—Two of the Pearl River pigs. Both had been weaned at eight weeks of age when they were substantially the same size. The pig on the left had been fed on standard meal plus aureomycin mould-extract. After six weeks the control pig weighed 42 lb; the other, 83 lb.

(*Below*)—These pigs were fed on an experimental diet of corn meal and peanut meal fortified with pure Vitamin B12 for 37 days. The pig on the right received aureomycin; the pig on the left did not. The pig that received aureomycin weighed 31 lb; the other one weighed only 22 lb.



Antibiotic+Vitamin=Boom Food

CHAPMAN PINCHER

ONE of the hardest questions which all manufacturers of antibiotics such as penicillin have to answer is how to dispose of the spent mould which remains after the drug has been extracted from it. This waste product cannot just be dumped into rivers because its decomposition would exhaust the water of its dissolved oxygen with the result that the fish would be asphyxiated. It cannot be burnt because it is too wet.

This problem beset the U.S. firm, Lederle Laboratories, when they began to produce aureomycin two years ago,* and it was passed to the research staff for solution. As so often happens when a firm faces up to its waste-disposal problems instead of shirking them, the waste product turned out to be a most valuable material.

Just how valuable it is, I was able to see for myself during a recent visit to the main Lederle plant and research laboratories at Pearl River, which is a township about thirty miles from New York.

Today the income derived from the spent mould far exceeds the income from the aureomycin itself.

Research showed that the soil mould *Streptomyces griseus*, from which the antibiotic streptomycin is extracted, contains vitamin B12 and that this vitamin promotes the growth of some animals. It seemed reasonable to suppose that the closely related mould *Streptomyces aureofaciens*, from which the golden aureomycin is extracted, might also contain vitamin B12. So the Lederle research team, led by Dr. E. L. R. Stokstad and Dr. T. H. Jukes, decided to try out the effects of feeding small quantities of the spent mould from the aureomycin plant to poultry. They found that when chickens were fed on a diet deficient in vitamin B12 they rapidly gained weight if waste aureomycin mould was added to their food. At first the scientists thought this was entirely due to the vitamin B12 in the mould. So they replaced the spent mould with pure vitamin B12, which increased the growth of the chicks *but not nearly to the same extent.*

Presence of Two Growth Factors

Experiments carried out by independent workers have proved that the spent mould must contain *two* growth-promoting factors—evidently there is another factor besides the vitamin B12. The Lederle researchers are now convinced that *this other factor is aureomycin itself.* They found that when purified aureomycin is fed, in place of the spent mould, in a properly balanced feed, the chickens showed the same spectacular increase in growth rate as had been produced by a diet which included the spent mould. (1–2% of the aureomycin produced inside the giant fermentation vessels—each of which holds 9000 gallons of liquor—remains behind in the mould after the filtering process. This small residue of aureomycin is not worth extracting commercially.)

Exactly how aureomycin exerts this stimulating effect on growth is still uncertain. Most probably it acts by altering the composition of the bacterial flora in the chicken's gut, weeding out certain types of bacteria and perhaps encouraging other types by thus removing their competitors. It may kill off bacteria which produce toxic substances that retard the growth of the chicken; or by subduing certain bacteria it may favour the multiplication of other bacteria capable of producing vitamins which the chicken needs.

There has been one recent research report that aureomycin may indirectly compensate for a deficiency in other vitamins of the B complex, such as nicotinic acid and riboflavine.

A few scientists think that aureomycin may produce its effects by influencing some endocrine gland or other. Such a mechanism has been suggested to explain the results of some German workers who found that two sulpha drugs—sulphamerazine and sulphamethazine—stimulate the growth of the combs of White Plymouth Rock cockerels when they are added to the diet. (Here the action of the drug is supposed to be on the pituitary gland.)

Use by Poultry Farmers

As a result of the discovery of this growth-stimulating effect, meal containing the aureomycin mould is now selling fast to farmers in the U.S. where chicken is "the poor man's meat". The demand from poultry farmers has been so great that the sale of aureomycin animal food has grown to be a $8,000,000-a-year business.

More than 90% of the commercial product is now made from mould specially grown for the purpose. No aureomycin is extracted from this mould for pharmaceutical needs.

Its vitamin B12-content alone would have ensured a ready sale for the mould, as this vitamin normally has to be added to poultry-meal, by mixing in some form of animal protein which is expensive. But the double growth-promoting value of meal containing aureomycin has made it extremely attractive to producers of table birds.

The Lederle Company dries and powders the mould from the fermentation vats, assays the aureomycin-content, then sells the powder to the makers of proprietary feeding stuffs. The processed mould is guaranteed to contain not less than 0·8% of aureomycin hydrochloride. The manufacturers recommend that it should be added at a level not exceeding 14 lb. per short-ton (2000 lb.) of ration, giving a final aureomycin content of roughly one part in 18,000.

The antibiotic simply speeds the rate at which the birds grow. It does not increase their final adult size. Prolonged feeding with it seems to have no ill effect on the health of the fowls or on the quality of their flesh.

I saw in the Lederle Laboratories the surprising results of feeding this meal to chickens. It normally takes 11–12 weeks to produce a 3 lb. fowl for 'broiling'. With the help of aureomycin a bird reaches that weight at about 9 weeks.

* A set of pictures showing details of the Lederle aureomycin plant was published in DISCOVERY (December 1949, pp. 384–5).

This abnormal rate of growth gives the bird a bigger appetite, so that it eats more food than a control bird. But as it reaches market size so much sooner, it eats less food in the long run. Pound for pound, therefore, aureomycin-fed birds are cheaper to produce. And the saving is considerable when thousands of birds are involved.

The growth-stimulating effect of aureomycin on chickens has been confirmed by British experiments carried out at the National Institute for Research in Dairying at Reading. Dr. S. K. Kon and his colleagues there found that pure aureomycin fed at a concentration of only one part in 80,000 parts of diet stimulated the growth of chicks and this happened whether they were deprived of vitamin B12 or not.

The aureomycin meal has also proved successful with turkeys. When I was at Pearl River, Dr. Jukes told me that there was some fear that millions of turkeys which had been given the food might have grown too big for the average American family's dinner when Thanksgiving Day (November 23) arrived!

Success with Pigs

After the success with poultry, scientists tried out the aureomycin meal on pigs. The pigs reached marketable size several weeks in advance of normally fed animals, though again the drug did not affect the final adult size. In this experiment Dr. Damon Catron of Iowa State College seems to have obtained the first success, and he reported that pigs grew 15–31% faster when given aureomycin. His result was confirmed by Dr. D. H. Schneider at the State College of Washington, and by the Lederle researchers.

At Lederle's experimental piggery I inspected groups of pigs which had been given the aureomycin meal, and compared them with control pigs fed on the same food minus aureomycin. The pigs which had been given the antibiotic were about 40% bigger on the average.

In one pen there were five 14-week-old piglets which had been fed on a standard pig-meal; their average weight was 44 lb. In the next sty there were five piglets of the same age and breed. They had been the same size as their neighbours when they were weaned six weeks earlier. Except for the addition of a small quantity of the powdered spent mould they had been fed on exactly the same meal mixture. *Their average weight was 65 lb.*

A comparable contrast in size was to be seen in several other matched lots of piglets. Dr. William Williams, who is in charge of these feeding tests, produced records of many other trials involving pigs of different breeds and ages. Almost invariably the result was that the pigs given the benefit of the antibiotic put on weight faster.

As in the case of poultry, the fast-growing pigs eat more food, but they utilise their food more efficiently, with the result that by the time they have reached market-size they have eaten substantially less food for every pound of flesh they have put on than normally fed pigs. (This point is brought out in one of the accompanying photographs.) The manufacturers claim that aureomycin can save up to 130 lb. of pig-meal for every 100 lb. of pork produced.

Perhaps the most surprising result of the Pearl River experiments has been the effect of aureomycin meal on undersized pigs. In nearly every large litter there is at least one piglet which is considerably smaller than the rest. This is usually a pig which was normally small at birth and so got off to a bad start in competition with its litter-mates for the mother's milk supply. These little 'runts', as they are called, rarely reach marketable size, and the wise farmer kills them off early. Now the Lederle scientists claim that when a runt is given the benefit of aureomycin in its diet it quickly makes up for its bad start, and becomes almost as big as its litter-mates.

The batches of piglets which I saw at Pearl River had each contained one runt at the start of the experiment. The runts were easy to spot in the control groups fed on standard meal, as they were barely half the weight of the 'best doers'. But in the aureomycin-fed batches the runts had grown to the same size as the rest. The antibiotic is not *always* effective in promoting the growth of runts, but it usually is. Runts may be dwarfed because of various defects.

The fast-growing pigs seem otherwise to be quite normal. The bacon and ham they ultimately yield is not excessively fat, and its flavour remains unaffected.

The practical value of these experimental findings has again been substantiated by the enthusiasm of the U.S. pig farmers. Pig-meal fortified with aureomycin mould is selling well in America. Dr. Jukes told me that the results have been almost too good! For example, the Minnesota meat packers have complained to their union because this year's pigs are reported to be getting to market so fast that they cannot cope with them!

Effects on Other Animals

Naturally U.S. scientists were quick to test the possibilities of aureomycin in the rearing of other types of animals. Trials with calves gave only slight positive results, so far as growth-rate was concerned. Bacteria living in the alimentary canal of ruminant animals are believed to play an essential part in the digestion of the cellulose in the herbage they eat, so any serious interference with the activities of these bacteria by antibiotics may be to the animals' disadvantage. But preliminary reports indicate that the aureomycin feed may nevertheless be of considerable value in calf-rearing. Dr. Williams claims that it helps to control the disease called white scours—a severe form of diarrhoea which kills many young calves.

The feed has also proved worthwhile in the rearing of mink. The animals are said to reach 'pelt-size' sooner than usual, and there is no reduction in the quality of the fur.

Whether aureomycin stimulates human growth has not been thoroughly investigated. In all cases where the drug has been used therapeutically, it has not been given for a long enough time to have any noticeable effect on weight or stature.

Manufacturers of other mould antibiotics are now actively investigating the effects of feeding farm animals on the waste from their fermentation plants. The spent mould left over from the production of terramycin (a new drug extracted from *Streptomyces rimosus*) is proving almost as effective as the aureomycin product. The main reason for this similarity seems to be the fact that neither antibiotic is put out of action by stomach juices. Penicillin on the other hand is inactivated by such juices, and therefore

(*Left*)—The amount of experimental diet (750 lb.) necessary to raise a 50-lb. weanling pig to the marketing weight of 200 lb. (*Right*)—The amount (500 lb.) of the same diet necessary to raise the same pig to 200 lb., incorporating aureomycin in the feed. The small pile of powder in the foreground is the amount of aureomycin needed in the latter diet.

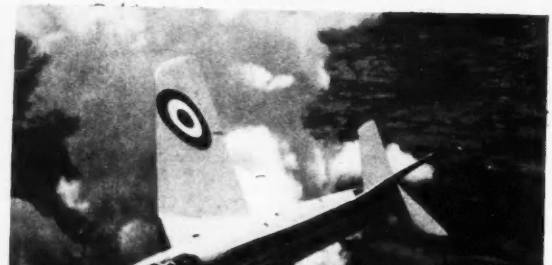
the spent mould from penicillin vats has no spectacular growth-promoting powers. But if pure penicillin is prepared in a special form so that it cannot be destroyed by the gastric juice to any great extent it apparently does promote growth in chickens.

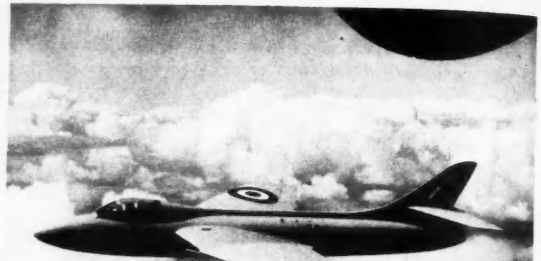
As aureomycin seems to save animal feed in a commercially profitable way it offers particularly attractive advantages to Britain. A plant for producing aureomycin is now operating at Hirwain, near Merthyr Tydfil, in South Wales. This, however, is not a full-scale fermentation plant, but a plant designed for purifying the crude extract of aureomycin which is imported in drums from America. Nevertheless the by-products of this plant could provide a substantial quantity of feeding supplement, and will probably do so in the near future.

Large-scale production of aureomycin feeding stuffs will have to wait until a fermentation plant for making aureomycin is built in Britain, and this depends largely on a political decision. So far the Health Ministry has not sanctioned the general use of aureomycin by family doctors, and practitioners may prescribe it for *only four* relatively rare complaints. The reason behind this policy is fear that a widespread Health Service demand for yet another expensive drug will result.

Meanwhile small-scale pig-feeding experiments in which aureomycin is being used are being carried out by three groups of British researchers—at the National Institute for Research in Dairying, at the Rowett Research Institute, Aberdeen, and the British Oil and Cake Mills at Stoke Mandeville.

From all this evidence there would seem to be no reason why aureomycin mould could not substantially increase Britain's supplies of home-fed pigs and poultry if it were made available.

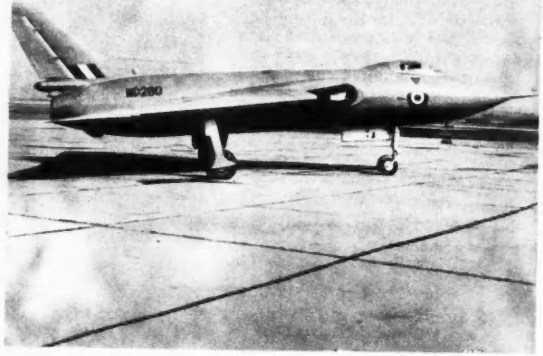




HAWKER P1067

AVRO 707A

VICKERS SUPERMARINE 'SWIFT'



VICKERS 'VALIANT'

The Delta-Wing Revolution

by Our Air Correspondent

THE AEROPLANE is on the verge of a revolution which will bring about a change in aircraft design so drastic that the external appearance will be completely altered. The revolution will not take place overnight, but even before the newest types now coming along are delivered to the squadrons of the Royal Air Force or to the world's airlines the 'next generation' of aircraft are already taking shape in the minds of our designers. These will be very different from those in current use: the aeroplanes of tomorrow will be 'flying triangles', or 'delta-winged', to use the favoured technical term.

Aircraft theory and design are necessarily a long way ahead of current practice, for a long time elapses between the drawing of the first designs and the quantity production of the new aeroplane; the development stage is a lengthy one involving as it does the designers' addition, after the prototype has been built, of many new improvements calculated to keep the plane as up to date as possible within the limits set by the basic principles of the *original* design. Thus it happens that delta-wing aeroplanes are being conceived today, at the same time as the commercial airlines are just beginning to get their first post-war designed machines and while the R.A.F. continues to be equipped with machines whose basic design was worked out during the war.

In the last few years, aircraft evolution has been rapid. Gas-turbine engines and very much 'cleaner' fuselage lines have given us aircraft that exceed the speed of sound at high altitudes. Even so, it has been a matter of evolution rather than revolution, and the aeroplane has remained a machine with a fuselage, wings, tail-plane, fin and rudder. It may look very different from the flying machines of earlier years, but is is essentially the same. Not so the delta-winged aeroplanes now envisaged by our designers.

The new types with swept-back wings, as are now being built for the Royal Air Force, represent a stage in the development of the delta-wing. The two latest and fastest fighters, the Hawker P.1067 (it has not yet been named) and the Vickers-Supermarine 'Swift', and the Vickers 'Valiant' four-jet bomber (which is acknowledged to be the world's most advanced bomber) all have swept-back wings. Thus our modern aeroplanes get more and more like an arrow-head in shape as speeds get higher and higher.

At the Society of British Aircraft Constructors' show on the Royal Aircraft Establishment airfield at Farnborough, Hants, in September, there were striking demonstrations of the new trend, both by the 'half-way' swept-wing aircraft, and by the fully delta-winged models on which considerable research is already being carried out in preparation for the new era.

The Farnborough show left three outstanding impressions:

1. The almost incredible speed of the new Hawker fighter;
2. That the fully delta-winged aeroplane is no freak and is clearly going to be the next step in aircraft design;
3. The performance of the 'Valiant' bomber.

The Hawker P.1067 has been described as the fastest fighter in the world, and those of us who saw Squadron-Leader Neville Duke, D.S.O., D.F.C., Hawker's chief test pilot, fly it across the Farnborough airfield only a few feet from the ground had no doubt that the claims that have been made for this remarkably fine fighter are justified. It isn't exaggeration to say that everyone present was awed by its speed.

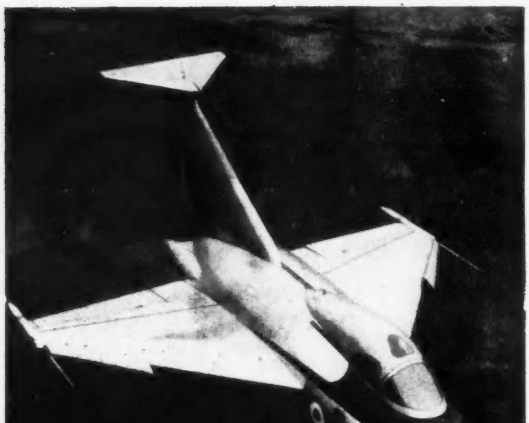
Although this aeroplane was demonstrated at Farnborough, and Squadron-Leader Duke gave a pretty good indication of what it can do, its full performance details are still a top secret. There can be little doubt that Squadron-Leader Duke exceeded on several occasions the official world speed record of 670 m.p.h. (which is held by an American F.86 Sabre jet fighter) by a very considerable margin. An American observer reported that "When he blasted past the watching technicians and journalists, he was travelling faster than any aeroplane I have ever seen fly—and that includes our F.86 Sabre." My own impression was that Duke was certainly not far short of 700 m.p.h., and it was gratifying to know that this fighter is in production for the R.A.F., even if it has not yet reached squadron service.

When the P.1067 was first allowed to be mentioned just before the Farnborough display, Mr. Neville Spriggs, Hawker's general manager, said that the fact that the R.A.F. had ordered the new fighter "off the drawing board" meant that the company had been able to plan its mass-production even before the prototype left the workshops for its first flight. Even the dimensions of this new fighter are secret. But with its swept-back wings and tail, it is certainly one of the most beautiful of all modern aeroplanes. It is powered by a Roll-Royce Avon gas-turbine, one of the most powerful jet engines.

Just as secret is the Vickers-Supermarine 'Swift'. We at Farnborough had hoped to see this Avon-powered, swept-back wing fighter, which is also already in production for the R.A.F., but a slight mishap kept it away, and its place was taken by the Vickers-Supermarine type 535, a very similar aeroplane but powered by a Rolls-Royce Nene engine. The 535 also showed astonishing speed, though one is probably justified in presuming, since it has a less powerful engine, that it is not so fast as the 'Swift'.

Both the P.1067 and the 'Swift' are the direct descendants of the Hurricane and Spitfire planes that won the Battle of Britain. The new Hawker is, in fact, the work of the design team headed by Sidney Camm, who was responsible for the Hurricane.

Flown by G. R. Bryce, Vickers' thirty-year-old chief test pilot, the 'Valiant' bomber showed us how the fashion in heavy bombers has changed since the war. This new, immensely powerful striking weapon, which is propelled by four Avon gas-turbines, seemed to glide through the air gracefully and effortlessly, and is obviously a very different proposition from the rather ugly and cumbersome-looking bombers of the war! And, though Bryce obviously had the throttles well back, it was apparent that



FAIREY F.D.1

this large bomber has great speed at its command. 'Valiants' are already in production for the R.A.F.

Soon the Royal Air Force will be getting these new fighters and bombers, and then our air force will have aeroplanes second to none in the world. But aviation progress cannot stand still, and if the P.1067, the 'Swift' and the 'Valiant' are the very latest types for immediate service three other little aeroplanes at Farnborough pointed the way to the designs of tomorrow.

These were the Avro 707A, the 707B, and the Boulton-Paul P.111—the experimental delta-wing machines. With the Fairey F.D.1 (which was not seen at Farnborough) these aeroplanes represent a progress report on recent researches carried out by our aviation scientists into the triangular wing. Only two of these planes flew in the Farnborough show—the 707B and the P.111; the 707A was exhibited only in the static display. Looking something like the paper darts we used to make when we were young—perhaps boys still make them, or are they too preoccupied with petrol-engined model aeroplanes?—these flying wings, all jet-powered of course, gave the Farnborough spectators a glimpse into the future. They are all comparatively small, single-engined aircraft, but looking at the new wing form it is not difficult to imagine even big bombers and airliners built to a similar configuration.

The precise nature of the researches that are now being conducted with these machines is naturally kept secret. But it is significant that the two '707's' have been built by the A. V. Roe Company, which is usually associated with large aircraft, such as the Lancaster and Lincoln bombers and the Tudor airliners. One imagines that the results of their investigations into the delta-wing will be applied ultimately to something pretty substantial.

The Boulton-Paul P.111, on the other hand, is thought to be associated with research on high-speed flight. This Wolverhampton firm is more usually connected with fighter aircraft, and the P.111, besides having a Nene engine as against the less powerful Derwent of the two '707's', has an extremely thin, fighter-like wing.

Wing Commander Roland J. Falk, Avro's test pilot, and Lieut. J. Elliott, of Boulton and Paul, showed the Farnborough crowds just how manœuvrable the new-style aircraft are. Both their machines were fitted with tail-parachutes which acted as landing brakes.

The 707B—designed for relatively low-speed research, whereas the 707A is used for research in the higher speed ranges—gave a brilliant demonstration of slow landing, an ability which is so sadly lacking in many modern aircraft. Landing speed is a subject on which many people have strong feelings; they say that before we concentrate our efforts on making aeroplanes fly faster, we should do something about making them touch down more slowly. So it was a joy to watch Wing Commander Falk, after doing a series of quick-succession rolls to illustrate how the delta-wing could be handled, bring the tail-less 'flying triangle' down in a high-angle landing, making full use of the wing area to slow down the aeroplane.

Actively interested in the delta-wing research are the experts of the Ministry of Supply, who control the Royal Aircraft Establishment and who have a joint interest with the R.A.F. in the experimental station at Boscombe Down, near Salisbury.

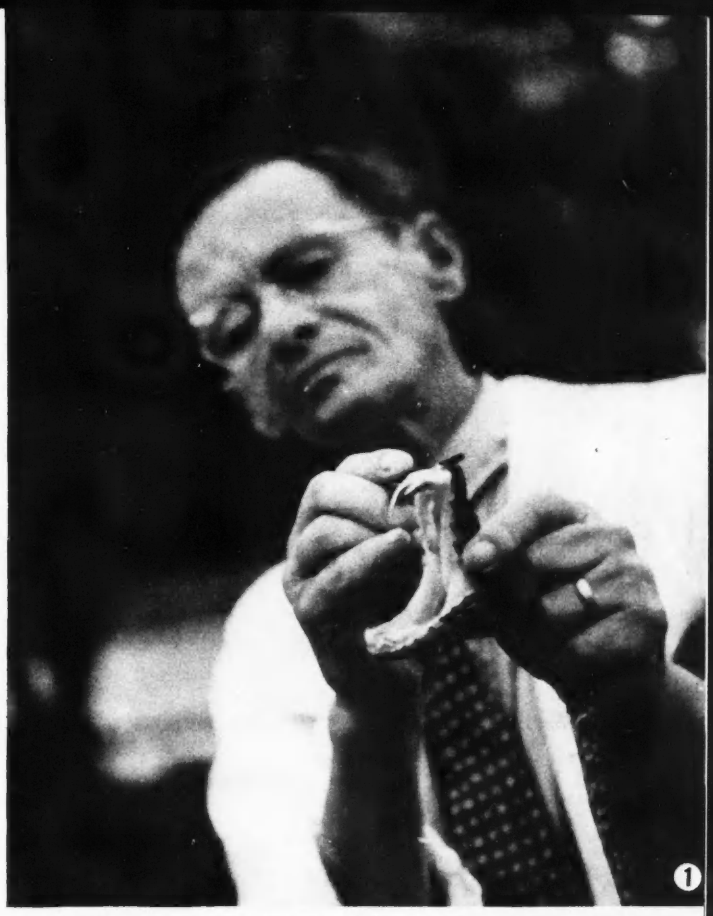
After the Farnborough show, Air Marshal Sir John Boothman, the former Schneider Trophy racing pilot who is now Controller of Supplies (Air) at the Ministry of Supply, visited Boscombe Down and flew the 707B for half an hour. Sir John, who is now fifty years old, said after his flight in the 'flying triangle' that it was a simple aeroplane to fly.

The two '707's' differ slightly from each other. The 'B' which first flew in September 1950, carries its air intake (like a dorsal fin) on top of the fuselage, while the 'A', a newer machine which made its first flight last July, has air intakes at the wing roots in the more orthodox manner of jet-engined aircraft. The 'A' has a slightly wider span—34 feet 2 inches—and is lower off the ground. The Boulton-Paul model has roughly the same wing-spread—33 feet 6 inches—but, at 26 feet, is 8 feet shorter than either of the Avro aircraft. The Fairey is the same length, but is smaller when measured from wing-tip to wing-tip.

Much development work has yet to be done, and doubtless more experimental aeroplanes of similar design will have to be built before even the research side of this development can be completed. But unquestionably these little single-seater aircraft are the forerunners of new designs, which will radically change the appearance of military and commercial planes.

The World's Largest Snake Farm

On the outskirts of Sao Paulo in Brazil stands the Butantan Institute, which has done more to combat snakebite than any other single institution. It specialises in the production of sera to counteract the effects of snake venom, and it also prepares vaccines and antitoxins used in the treatment of bacterial diseases, such as the Brazilian Spotted Fever. Founded in 1892 as the Brazilian counterpart of the Pasteur Institute, it now maintains the largest Snake Farm in the world. In pillbox-like huts are kept over 25,000 snakes of all kinds, poisonous and non-poisonous, which are used for study and experimentation. To encourage the Brazilians to send in fresh living specimens, the Institute presents every person who forwards a snake either money or an ampoule of anti-snake-venom; for every five poisonous snakes the sender receives a hypodermic syringe. Every year 15,000 to 20,000 snakes are received from the State of Sao Paulo alone.



1

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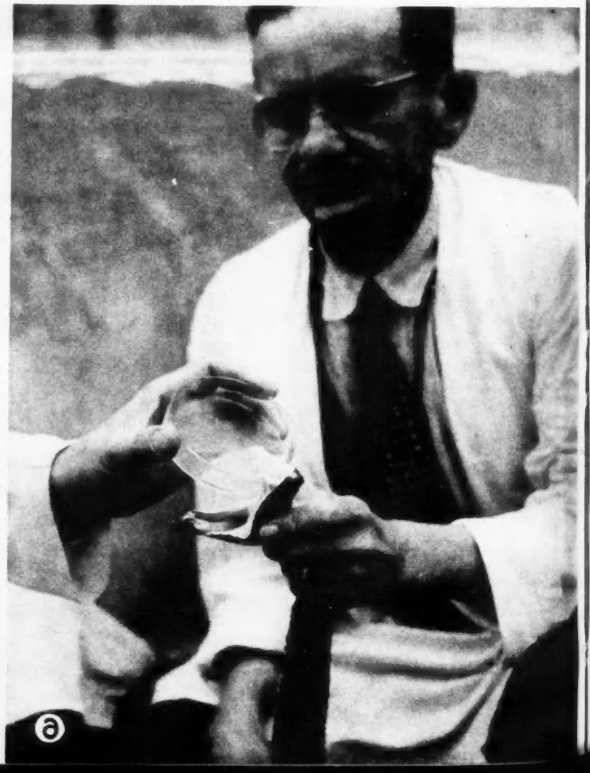
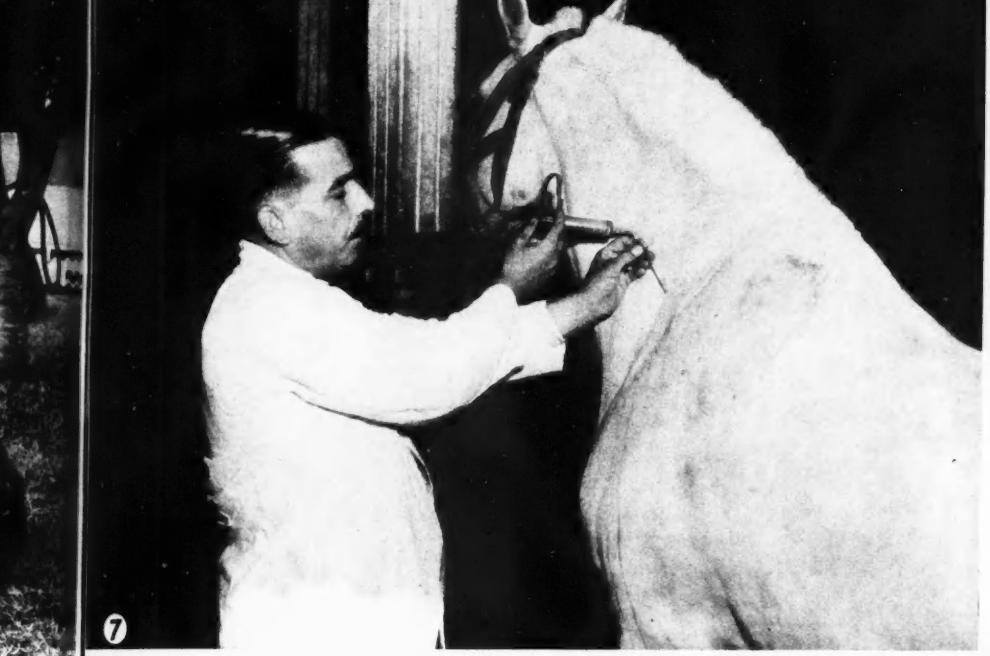
3. *The attendant at the Institute removes a new arrival from its box.* 4. *The attendant lifts a poisonous Urutu (this is the local venomous species whose Latin name is Bothrops alternata) with an iron hook on the end of a long rod. Once the snake is uncoiled he holds it at arm's length by its tail.* 5. *A stick with a leather noose is used to handle the viper.* 6. *A snake is milked of its poison. This procedure can usually be carried out only twice with one specimen, with the result that replacements of the poisonous species are needed in large numbers.*

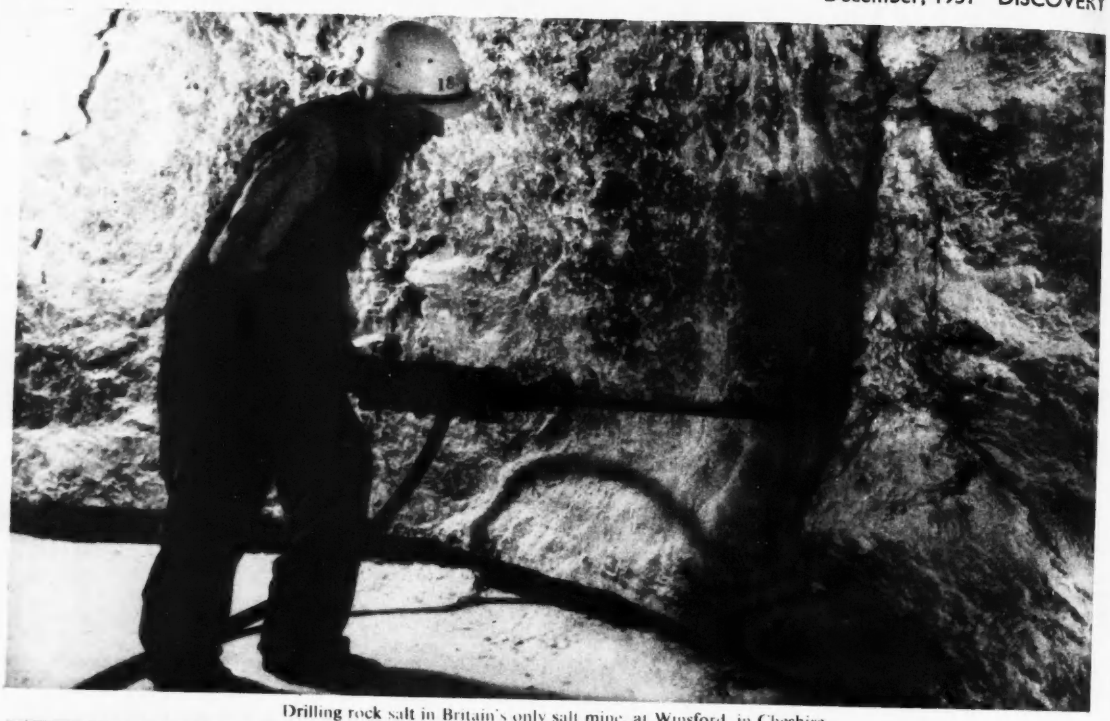




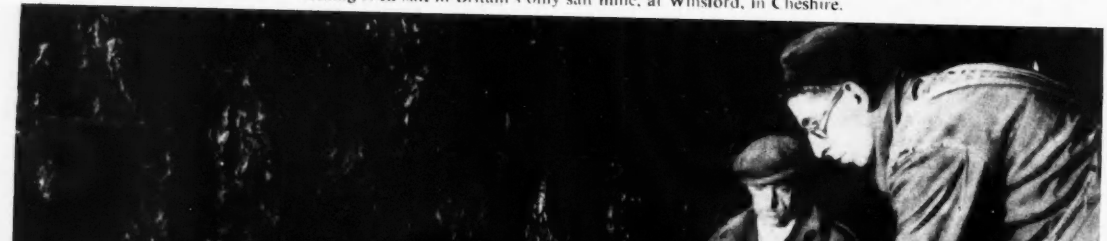
7. *In their reaction to the snake venom, these animals produce a surplus of anti-toxin, which remains in the blood. At the appropriate time blood, up to 5½ quarts, is taken from the horse's neck. The serum prepared from this remains effective against snakebites for a year. It is assayed on pigeons before release for use on human patients.*

8. *For injecting horses or mules, snake venom is used rather than the liquid venom, so that the strength of the injection may be more readily controlled. Crystals are obtained by dehydrating the venom in laboratory ovens. The venom is dissolved in water when needed for an injection.*

9. *The Butantan Institute works on other animal poisons, and for this reason keeps specimens of poisonous toads, scorpions and spiders. The toad seen here is a Bufo marinus, or Giant Water Toad.*



Drilling rock salt in Britain's only salt mine, at Winsford, in Cheshire.



Undercutting the rock salt in the Winsford salt mine with modern machinery.

Sodium Chloride: The Salt of Life

Continued from p. 362]

J. A. PARSONS

To RETURN to more distant history, the need for salt which goes with cooking must first have been filled by crystals from the inland salt-licks which animals often find, and in warm climates from pools at the coast. There are many salt marshes in Mediterranean lands where big deposits of salt are formed. In such places it would be simple enough to improve on the natural production of salt by providing extra ponds which can serve as evaporating pans, adding firm bottoms to the pans in order to reduce contamination as far as possible. Indeed, the very earliest records show that salt working of this kind was an established activity. All naturally evaporated salt contains some soil, which gives it a grey, brown or red tint. The crystals which are obtained have grown slowly and have therefore reached a large size. Salt with big grains, greatly valued for the curing of fish and other uses, is now known in general as *bay salt* even when it is factory-made. (The name *bay salt* was originally given long ago to salt from the bay of Noirmoutiers, near the mouth of the Loire.)

Artificial heat must be used where the sun's heat is insufficient. The most primitive method is described by Pliny, and by Caesar, who saw it being used by many conquered tribes. Brine, obtained from the sea or inland springs, was simply sprinkled on burning wood as fast as the fires would stand. Pliny says, "In Gaul and Germany, they pour salt water over burning logs. Oak is best, having a clean ash and producing plenty of salt; elsewhere hazel is recommended. When the liquid has been poured on, even the embers turn to salt. From whatever wood it is produced, the salt is black." The first advance was to heat large stones in the fire, remove them to a clean piece of ground and then sprinkle brine over them. This was done in very earliest times by workers on the salt mountains at Berchtesgaden, in Bavaria.

Salt obtained by such means is very crude, retaining all the magnesium and calcium chlorides from the brine; it also contains potash, derived from the wood. Such salt is strongly deliquescent. But when brine is evaporated in bulk the salt thrown down first is quite pure, and the more soluble impurities are concentrated in the solution that remains. Evaporation is therefore stopped before the deposit becomes contaminated by these impurities. The salt crystals are then washed. The mother liquor (*bitterns**) furnish a source of potash and bromine which is exploited in some countries.

The Romans spread the use of lead pans all over Europe, and it was with this invention that bulk evaporation of brine became possible. Apart from producing a better salt, the invention meant that the fuel could be used more efficiently. But only wood could be burnt in contact with lead, as the sulphur present in coal rapidly attacks this metal. The demands of a large salt refinery for wood were relatively enormous, and this aggravated the problem which had originally arisen because of the demands of the iron smelters for large amounts of charcoal—charcoal was then essential for iron smelting, and the charcoal burners were using up British trees at a great rate. The problem grew steadily more serious, for the woods and forests were being rapidly devastated at a time when the *wooden* ships of the Navy were the main guarantee of Britain's safety against foreign invasion. In the seventeenth century it fortunately became possible to make riveted pans of iron, and this enabled the salt refiners to use coal instead of wood. Coal is still the main fuel used in salt refineries, though oil is used for the purpose in the United States.

One other method of brine concentration is used in cold countries, especially Russia. This method is of great antiquity. Brine is allowed to freeze in pits, when pure ice separates, leaving behind a stronger brine, which can contain as much as 14% salt at about $-10°$C.

It is a peculiarity of sodium chloride that its solubility rises very little with the temperature; this is 26·3% at 0° C. and at 100° C. only 28·2%. For this reason it is not produced by cooling a hot solution; it is obtained instead by steady evaporation at a raised temperature. As is true for all salts, the more rapid the crystallisation, the smaller are the crystals which form. Fine white table salt results from vigorous boiling and rapid evaporation, while artificial bay salt comes from pans which are maintained for a long time some 30° C. below boiling point. The many other grades of salt needed in commerce are intermediate between these extremes. For large crystals, pans still have to be used, and are even now nothing but steam-heated and enlarged versions of the Roman model.

Modern chemical engineering has made possible great improvements on this process. For example, multiple-effect vacuum pans for salt refining were introduced in America at the end of the last century. Vacuum salt is the cheapest refined grade on the market, but being produced by rapid evaporation it can only have small regular crystals. The salt crystals are removed continuously from the pans by means of bucket or screw elevators.

The latest development in salt refining, which is only a few years old, returns to the system of using a single pan unit. Known as *Vapour Recompression*, it most ingeniously achieves even greater efficiency than the vacuum process. The steam, which boils off under weak vacuum, is compressed by a turbo-compressor, and this superheats the steam by a few degrees. The steam then proceeds through heating coils which warm the brine.

The best of the old open pans with steam heat give some 2 tons of salt per ton of coal. The vacuum system is three times as efficient, and the vapour recompression system achieves an output of 17 tons of salt for every ton of oil that is burnt.

Among the eight elements which together make up 97% of the earth's crust, sodium takes sixth place. Supplies of

* The word *bitterns*, commonly used in this context, is now defined as the bitter mother liquor that remains in saltworks after the sodium chloride has crystallised out. It is actually a contraction of *bittering*, and dates back to 1682. It was also applied to a bitter tincture of quassia and other substances used in adulterating beer.

salt are virtually inexhaustible, and they are very widely distributed. Huge deposits of solid salt are mined in many places. All inland brine springs are the result of a stream of fresh water running through underground deposits. All the massive salt deposits are believed to have been formed in the distant past when inland seas and lakes dried up, a process which can be seen going on today in several places. Salt deposits vary from practically pure salt of an almost snowy whiteness to saline earths which contain only 5–10% of the mineral.

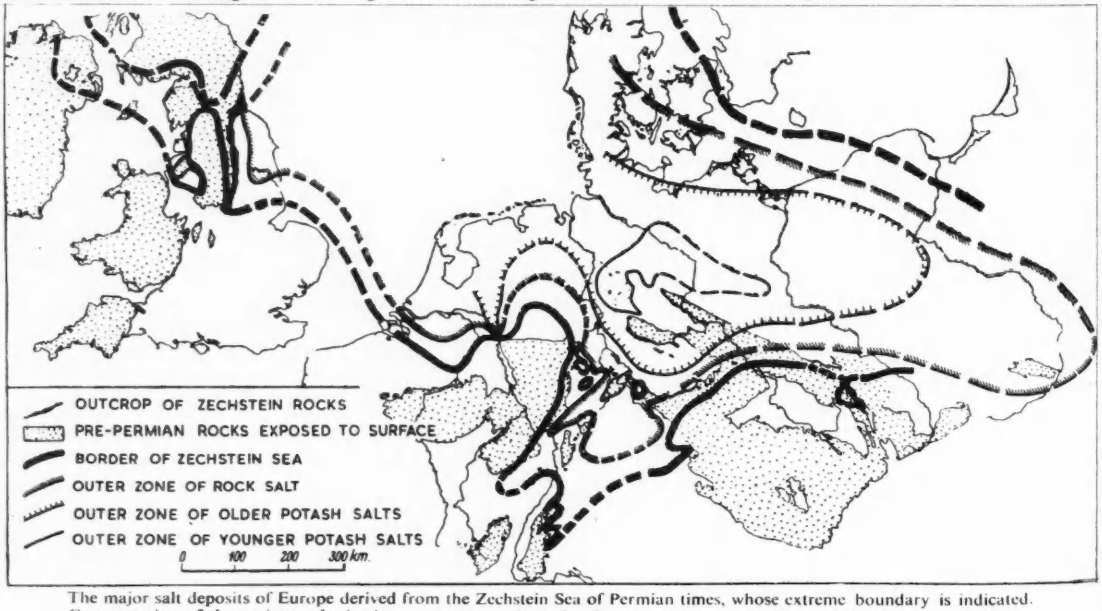
As already mentioned, blocks of salt are simply hewn out of some Eastern mountains for immediate sale. At many mines in the U.S.A. and Poland, for instance, the material is pure enough to be crushed directly into sacks, though unless specially treated such salt tends to re-solidify in time. But from other deposits the salt is brought out, dissolved and then crystallised; alternatively water or dilute brine is pumped into the mine, and a saturated solution of salt withdrawn to be concentrated by one of the methods already described.

A grave problem of large-scale salt mining is the risk of subsidence of the overlying ground. In Cheshire, where brine springs were known long before the Romans, the first recorded case of subsidence occurred in 1533. This was more than a century before rock salt was first found there; the subsidence was due to no other cause than the raising of natural brine. But the evil has increased with production, and in the first few decades of this century extraordinary sights could be seen in the districts of Northwich and Winsford; whole houses began to tilt sharply, and whole buildings sank until their roofs were only just visible above the level of the roads which they fringed. Other more sudden catastrophes occurred; there was, for instance, the complete collapse of a canal bed, which stranded many barges and caused great damage. For a long time the mining interests resisted claims for compensation. But about the turn of the century compensation became an accepted practice. There is no doubt that this led to a decrease in subsidence damage due to underground workings.

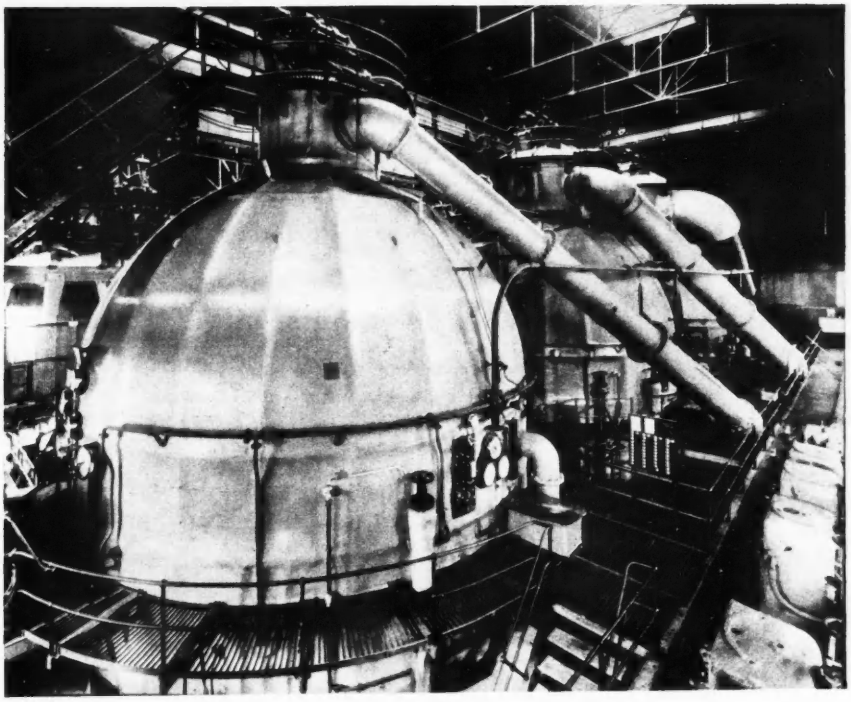
The mining of every substance won from the earth tends to develop its own particular character and traditions. Certainly the nature and atmosphere of salt working have been very different from those, for instance, of coal mining. Salt mining is more healthy, and salt miners remain fit and strong to a good age. They have generally had a great love of tradition and mystery; they have had some curious and fascinating customs. The owners of salt mines, on the other hand, have shown themselves almost unbelievably conservative and resistant to new improvements, and this is true all over the world.

The romantic extravagance of the Wieliczka mines, some ten miles south-east of Cracow, under the Austro-Hungarian Empire is notorious. Worked largely by convict labour, they were infamous throughout Europe for hundreds of years. The early workings were made without adequate shoring, and entire streets of the old town of Wieliczka subsided with heavy loss of life. The underground vaults and chambers now extend over more than twelve square miles, each a maximum depth of 12,000 feet, and include sights that are quite unique. There is a vast ballroom with pillars, statues, and huge hanging candelabras, all made from crystal salt, where festivities were still held between the world wars. In addition there are great underground lakes, and a sumptuous chapel where services were celebrated until a few years ago. The Austrians were traditionally very secretive about the mine, concealing figures of output and working costs.

It is safe to say that there is no country where the resources of salt once fully developed would be insufficient to cover all its needs. In pre-Roman times only in desert


OUTCROP OF ZECHSTEIN ROCKS
PRE-PERMIAN ROCKS EXPOSED TO SURFACE
BORDER OF ZECHSTEIN SEA
OUTER ZONE OF ROCK SALT
OUTER ZONE OF OLDER POTASH SALTS
OUTER ZONE OF YOUNGER POTASH SALTS
0 100 200 300 km.

The major salt deposits of Europe derived from the Zechstein Sea of Permian times, whose extreme boundary is indicated. Concentration of the various salts in the sea water was brought about by solar evaporation, and fractional crystallisation proceeded in the following order: calcium sulphate, sodium chloride, and lastly the highly soluble sulphates and chlorides of magnesium and potassium. These fractions gave rise to the rock salt and other deposits which are indicated.



A VACUUM EVAPORATOR AS USED FOR PRODUCING SALT FROM BRINE

regions of the East was salt carried long distances, because each tribe could usually supply its own needs. Yet today the few big exporting countries alone (*see* Table II) do an aggregate trade amounting to two and a half million tons a year. In the past, shortage of salt has been a compelling factor in the history of many countries. With the development of shipping, the large and easily worked deposits captured the markets, and uneconomic deposits were ignored. This trend was not reversed until the nineteenth century, when mechanical methods, and the stimulating demands of the growing chemical industry, made many countries aim at self-sufficiency again. This reverse trend is still operating. Denmark, for instance, which has been dependent through all her history on South European suppliers, discovered large deposits within her borders in 1945 and is likely to become independent in the near future.

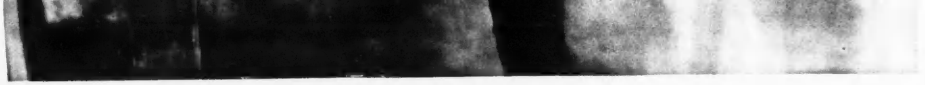
Salt is one of the most important raw materials of the chemical industry, and its immense needs are now met largely by brines. The accompanying chart shows the principal products derived from salt, with a selection of secondary derivatives. Apart from this use of salt and its domestic consumption, the biggest uses for salt today are for meat packing and fish curing, for cattle feed and for salt licks used in dairying, the tanning of hides and dyeing. Great quantities are also used in refrigerating systems, and for unfreezing snowy and frozen roads, as a fertiliser for some crops (e.g. sugar beet), for glazing earthenware, and for regenerating water softeners.

The position of a country deprived of salt in the Middle Ages was very difficult. Then the only way to preserve meat fish and butter was by salting, and large quantities of salted food were needed to provision the Army as well as to provide out-of-season nourishment for the civilian population. Some religious practices also came to depend to a limited extend on salt, for preserved fish was almost the only food available to those who strictly observed the long fasts.

It is hard now to believe that once upon a time England was dependent on imported salt. Yet this was so for many centuries. Home-produced salt must at that time have deserved an unenviable reputation, due to the fact that it was heavily contaminated with magnesium chloride and sodium sulphate; such salt damps badly and it would be unpleasant even as table salt. In those days great quantities of bay salt and fine salt were imported. The Dutch salt was very pure and was particularly valued for fine provisions. A great deal of salt also came from France. Poland, Hungary and Italy were among other suppliers; the latter in particular

TABLE II
SALT PRODUCTION IN 1947

	Production (*long tons*)	*Exports*
U.S.A.	14,409,263	168,131
Great Britain	3,138,899	147,963
France	2,574,241	183,614
China	2,220,864	174,319
Germany (British, French, U.S. zones)	1,796,232	not available
Italy	1,367,738	302,033
Spain	821,409	339,195
Poland	609,949	28,956
Egypt	350,000 (estd.)	613,263 (abnormal year)



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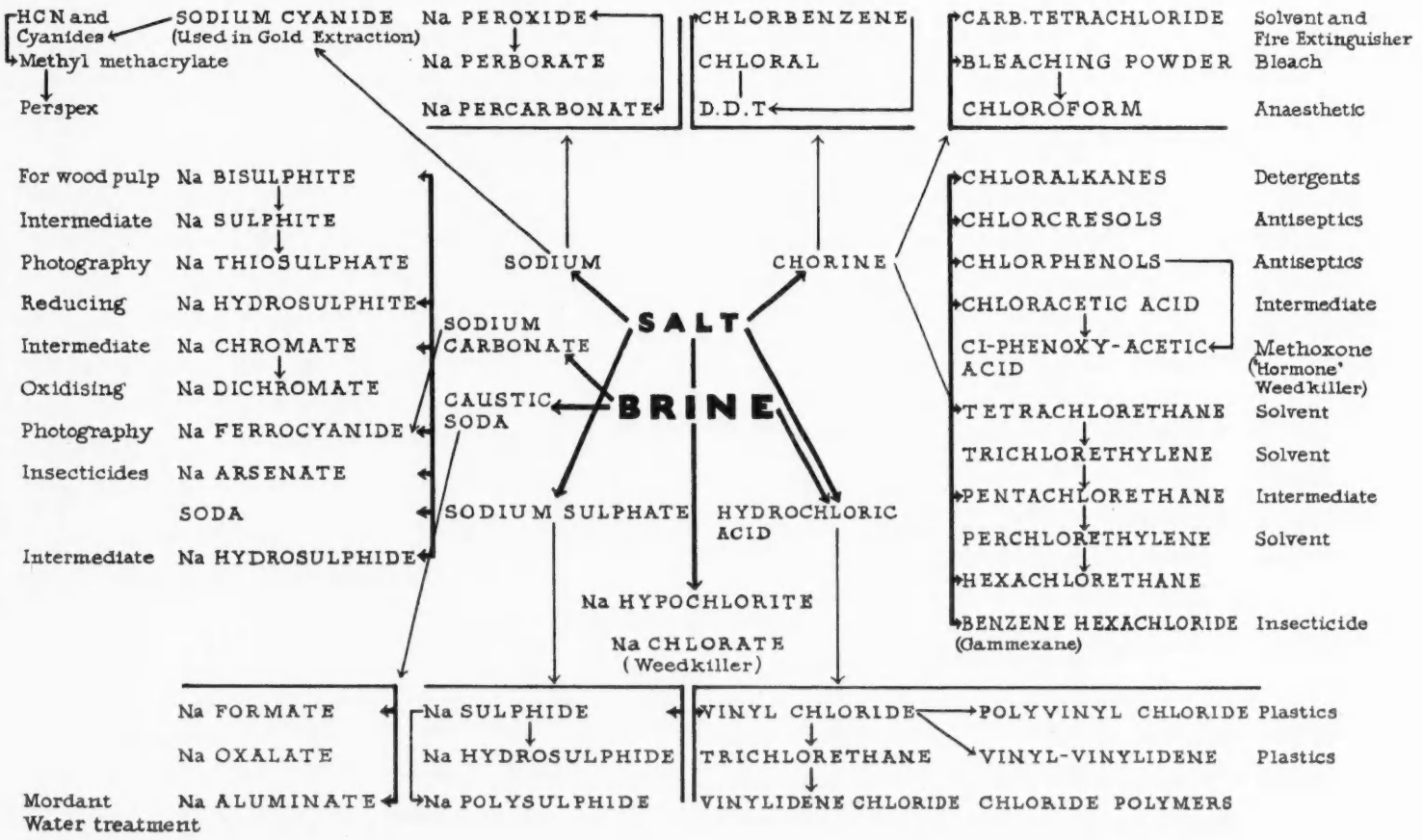
DERIVATIVES FOR COMMON SALT



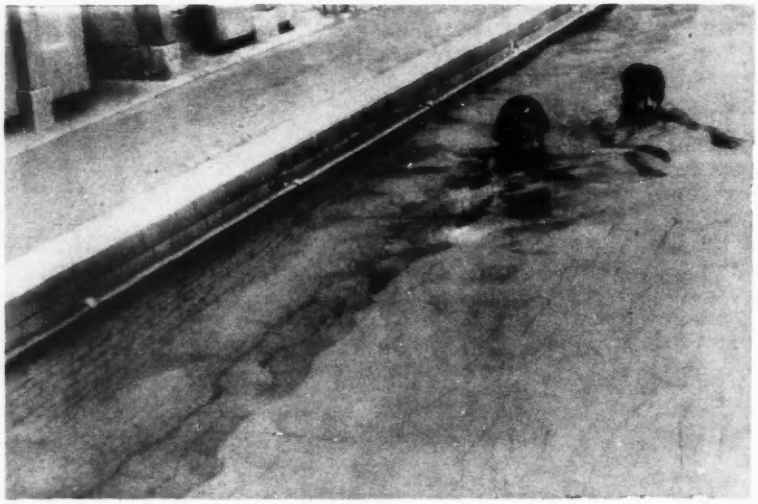
Ladling out salt from an open evaporator into a mould. A row of full moulds is seen on the right. This is the origin of 'block salt.'

supplied salt to the Cornish pilchard fishery, who until recently were still buying from Italy. The rise of the salt imports from these countries was partly connected with our large export trade in wool.

Manufacture of salt on a large scale in England began only after rock salt deposits had been discovered during a search for coal near Northwich in 1670. The diarist Celia Fiennes, who held a mortgage on the Marbury estate on which the find was made, described salt-working in her *Journeys*. Many small boilers had of course worked on the coast and at salines since pre-Roman times, but their output was trivial. Salt boiling was one of the first technical subjects in which the Royal Society took an interest; many reports, which compared analyses of English and foreign specimens of salt, appeared in the Society's *Philosophical Transactions* in the early eighteenth century. The British Parliament also encouraged production and endeavoured to spread knowledge of new methods of handling salt.

The standard of purity of British salt began to rise, but prejudice against the home product persisted for many years. The prejudice was gradually weakened by cutting off foreign supplies; for instance, Dutch imports of salt were interrupted in the seventeenth century, and those from France failed for long periods during the Wars of the Austrian Succession.

The real political dominance of salt in a dependent country can be perfectly illustrated from the history of Switzerland. Her high mountains with their excessively soft waters have always made the use of salt in quantity essential for the well-being of both men and animals. The first native source was found only as recently as 1560, and this was but little developed. Until about 1650 France monopolised the European trade in salt. Politics entered into this trade towards the end of the fifteenth century. The bulk of French supplies then came from Burgundy, which was subject to many conflicting influences; originally an independent kingdom, it had become a dukedom, and went to Louis XI by the Treaty of Arras in 1482. Its salt production was on a small scale, but the markets for this material were large. Its merchants had dealt widely with



The electrolytic process of making soda from salt released huge quantities of chlorine for industry. This chlorine has found many uses; it is used for chlorinating water (in swimming baths, etc.) and for bleaching purposes, and it is also a raw material for the manufacture of a great variety of chemicals, as indicated in the chart on p. 390.

Courtesy, Baths Superintendent, Royal Borough of Kensington.

the neighbouring salt producers of Franche Comté and with salt producers on the Mediterranean coast a few hundred miles to the south. By the Treaty inland salt was excluded in favour of that from the sea.

But the son of Louis XI, proposing a campaign in Italy, bought peace on his eastern borders by giving Franche Comté to Maximilian I, the powerful Emperor of Germany. He had to include in this gift the right to renew the valuable salt trade with Burgundy, and he reversed the previous arrangement by excluding sea-salt for ten years, a period later several times prolonged. This made the Swiss indebted for salt to Maximilian of Germany at the very time when the Forest Cantons were starting the gradual unification which was eventually to lead them to independence from the German Empire. Maximilian had a low opinion of the Swiss: "An ill-conditioned, rough, and bad peasant-folk in whom there is to be found no virtue, no noble blood, and no moderation, but only disloyalty and hatred towards the German nation."

Friction was understandable, and was one of the causes of the Swabian war and the Swiss war of independence. Again, in 1538, the supply of salt from Provence to Berne was made conditional on the agreement of the latter to follow Provencal policy with regard to Franche Comté. The market gradually widened as other French and Austrian salt producers entered into it, and the Swiss were able to use their growing prestige to secure other supplies. Salt sanctions against the Swiss could no longer be enforced by 1677. German salt from Reichenhall and Hall had then virtually captured the market. The picture is completed by the later exploitation of great deposits within Swiss borders, mainly around Bex and Rheinefelden. (In 1948 Swiss production was 107,000 long tons; only 382 tons were imported.)

The world's production of salt in 1948 was 42,000,000 long tons. The turbulent role of salt in history is now finished. As an article of food it is now taken for granted in many parts of the world. But however plentiful salt becomes, we cannot quite forget its ancient importance. Its names are embedded in all languages, and written into all maps. The Roman legions were at first paid in salt and other necessities; from the term *sal-dare* come the words *soldat* and *soldier*, as well as *salary*. From a list of European place-names one can pick at random *Hall* and *Hellkettles* (*hals* is the Greek for 'salt'), *Salamis*, *Salzburg* and *Seille*. The *Via Salaria* is one of the oldest roads to Rome.

Innumerable superstitions connected with salt can be found in the *Golden Bough* and kindred works; some still persist in the minds of living people. As a symbol of hospitality, in the East salt is said still to have all its full savour. "To put salt on its tail" and "to sit above the salt" are phrases still in use. To spill salt has long been regarded as an evil omen; Leonardo da Vinci's *Last Supper* shows a spilt salt cellar by the hand of Judas.

However much salt is used as an industrial chemical, a preservative, a fertiliser or a form of currency, its greatest importance lies elsewhere. Dissolved in the cooking pot or served as table salt, it will always remain what it has always been—the indispensable mineral which maintains within the body of man that relic of the ocean without which he cannot live.

The photos illustrating this article are reproduced by permission of I.C.I. Ltd.

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A. F. CALVERT, *Salt in Cheshire*. (London, 1915.) A long account, rather diffuse, but containing a wealth of facts.

A. F. CALVERT, *Salt and the Salt Industry*. (London, 2nd edn., 1929.) A short but useful small survey.

EDWARD HUGHES, *Studies in Administration and Finance*. (Manchester, 1934.) A fine account of salt taxation, with special reference to its history in England.

J. O. VON BUSCHMANN, *Das Salz* (2 vols., Leipzig, 1906 and 1909.) A thorough and encyclopaedic work.

WILLIAM BROWNRIGG, *On the Art of Making Common Salt*. (London, 1748.) The most fascinating and readable of the shorter general accounts. *The last three works are especially rich in references.*)

The latest figures for British salt production are published in the Board of Trade's Final Report on the Census of Production for 1948, Vol. 1, Trade C, *Salt Mines, Brine Pits and Salt Works* (H.M. Stationery Office, 1951, price 1*s.* 3*d.*)

I.C.I. have made a film called *This is Salt*, which shows the Winsford salt mine, and the preparation of salt from brine by both open pans and multi-stage evaporators. The film may be borrowed from: I.C.I. Film Library, Bolton House, Curzon Street, London, W.1.

Colour matching is an important procedure in quantitative chemical analysis, as depth of colour provides a measure of the concentration of a coloured substance in solution. Colorimetry has numerous applications in industry, and in biology it provides a convenient method of describing colours, of bird plumage for instance.

Tintometer Colour-matching Techniques

C. L. BOLTZ

THERE is no mystery about the matching of colours: all of us have had to do it at one time or another, whether with wools, suitings, paints, or other coloured materials. It is merely a comparison and a private estimate of when one colour is equivalent to another in chromaticity (i.e., in colour value) and, usually, in lightness, that is, apart from the chromaticity, the judgment whether one specimen is lighter or darker than the other. Any such comparison is purely qualitative; it is done under a variety of lighting conditions; it is commonly done with a fairly large patch of coloured material.

When this comparison of colours is done under carefully controlled conditions it becomes a scientific technique, and it is now used in a large number of industries and professions.

The first refinement is to limit the size of patch viewed in order to bring the retinal image on the part most sensitive to colour (chromaticity)—the foveal area.* This control is usually imposed by setting a standard figure for the angle subtended at the eye by the patch of colour, and this is two degrees.

The second control is to ensure a standard illumination.

The third control is to make one colour variable in a known way. The most widely used way of doing this is to make one colour a resultant of three components, for experience has shown that three colours are needed by people with normal colour vision in order to match any other colour. Four are not necessary; two are not enough. (This is the inexorable fact on which the trichromatic theory of colour vision is based.) The components may come from filters interposed between the observer and a source of white light, or they may come directly from a spectrum. If the wavelengths of the used lights are known and their quantities can be controlled, the purely qualitative comparison of colours becomes a quantitative matching.

There are many other controls that help to make the experiment more adaptable to various purposes, and to ensure exactly-repeatable conditions. Thus an instrument is needed; a colorimeter. A colorimeter of this complexity, such as the Wright colorimeter perfected at Imperial College, is an elaborate affair, and it is a piece of precision engineering and therefore very expensive—costing something like £1000 or so. Frequently one finds that only one example of such an instrument exists, and moreover it usually takes quite a high degree of skill to use it.

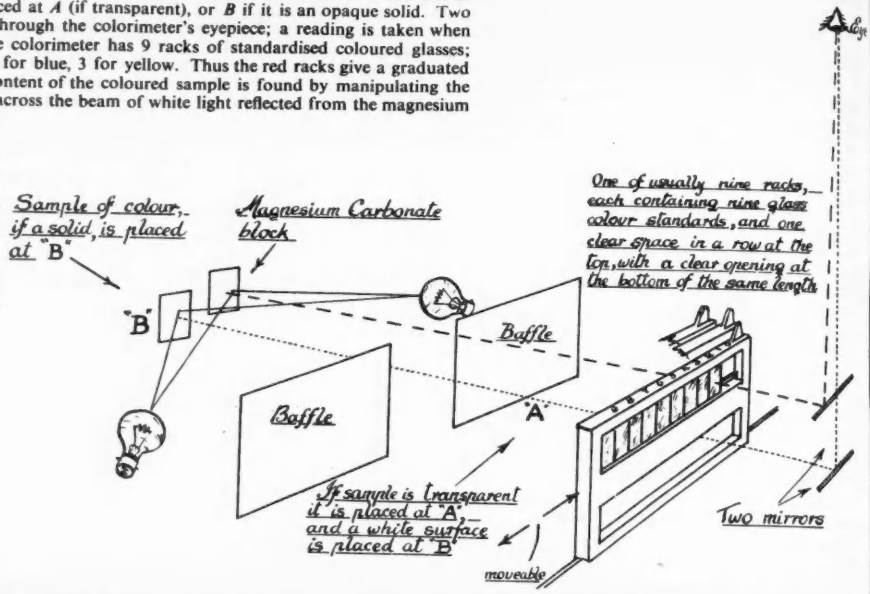
The Tintometer Ltd. has contrived to produce a colorimeter that is comparatively inexpensive and needs only slight skill, which can very soon be acquired. This colorimeter has certain limitations, but it is rarely that an ordinary user wishes to operate outside its limits of accuracy. It is therefore an instrument which is very useful for schools and colleges and industries. The three controls mentioned above are embodied in the instrument: smallness of field seen, standard illumination, the variation of the matching colour in a known way. This third control is special to the Tintometer. Between the eye and a white-light source—in the early days this was always north daylight, but it is now an electric lamp with a blue filter—are interposed a number of coloured glasses. These glasses are made in three colours; red, yellow, blue. Within each colour, the glasses are graded in such a way that, for example, two glasses of value 0·1 produce the same effect as one glass of value 0·2. Thus the values in each colour merely have to be added together to give the Tintometer value. By means of convenient slides the observer moves in and out the various glasses until the colour seen matches the test colour. The Tintometer specification will then be in terms of a number for red, a number for yellow, and a number for blue. This is quite an arbitrary way of specifying a colour, but it serves well enough for people relying on the Tintometer system alone. The arbitrariness of the system probably derives from the fact that when J. W. Lovibond devised it in 1885 there existed no accepted system of colour description other than the words in common use. (Lovibond had actually started in 1884 with a series of glasses for grading beer and malt. In the recent war a floating brewery was established for troops in the Pacific zone and Lovibond glasses were used for the grading.)

The arbitrariness of its system of colour specification in no way interferes with the efficacy of this colorimeter. In fact, a slightly changed form of the Tintometer colorimeter, with refinements added on the advice of Dr. R. K. Schofield of the Rothamsted Experimental Station, has been in production for some years. With this improved apparatus a very wide range of practical colours can be specified either in terms of the international C.I.E. system (Commission Internationale de l'Éclairage) or in terms of dominant wavelength and purity.

Tintometer Ltd. make their own glasses, which are graded by girls so trained that they have an almost incredible ability in discrimination. These glasses are permanent. Some criticism has been made of them on the grounds of inconsistency between glasses of the same number, but this criticism, made at a very high level, has been shown to

* The foveal area (otherwise called the *fovea centralis*) is an area of the retina where the light-sensitive cells are nearly all *cones*, relatively few *rods* being present. The cones are the colour-sensitive elements of the retina, and so the fovea is the most acutely colour-sensitive region in the eye. It should also be remembered that cones are used, to quote Prof. Ida Mann, for "acute vision in bright light," as well as for colour perception; rods on the other hand are "most useful . . . at low light-intensities . . . you will use your rods by moonlight when you distinguish only shape and distance, particularly of moving objects, but not colour."

FIG. 1.—Diagram showing the principle of the Tintometer Colorimeter. The colour sample to be assessed is placed at *A* (if transparent), or *B* if it is an opaque solid. Two patches of colour are seen through the colorimeter's eyepiece; a reading is taken when the two patches match. The colorimeter has 9 racks of standardised coloured glasses; there are 3 racks for red, 3 for blue, 3 for yellow. Thus the red racks give a graduated range of redness. The red content of the coloured sample is found by manipulating the red racks (these racks slide across the beam of white light reflected from the magnesium carbonate block) until the patch of colour corresponding to the sample exactly matches the red light reaching the eyepiece through the appropriate combination of red glasses. The same procedure is repeated for the blue and yellow content of the sample. The final result is given in terms of a figure for red, *plus* a figure for blue, plus a figure for yellow.


Sample of colour, if a solid, is placed at "B"
Magnesium Carbonate block
One of usually nine racks, each containing nine glass colour standards, and one clear space in a row at the top, with a clear opening at the bottom of the same length
"B"
Baffle
Baffle
"A"
If sample is transparent it is placed at "A", and a white surface is placed at "B"
Two mirrors
moveable

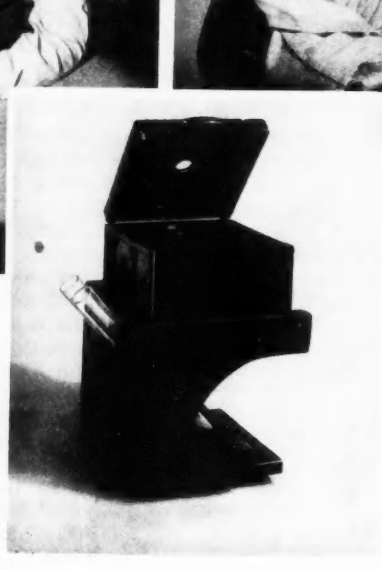


FIG. 2 (*above*).—The Lovibond-Schofield Tintometer gives the same sort of colour measurement as the colorimeter of Fig. 1, in terms of three figures which can be translated into C.I.E. units by consulting the graphs seen in the background.

FIG. 3 (*left*).—The all-purpose Lovibond Comparator, convenient for chemical analysis, etc. The standard coloured glasses are inserted in the holes in the disc; according to the type of coloured compound to be estimated, the instrument can be adjusted by altering the range of colour glasses on the disc, and the depth of coloured solution in the cell can also be altered.

FIG. 4 (*above*).—Lovibond comparator for routine tests. The operator is seen rotating the disc to get the right match.

derive from the wrong use of the glasses in apparatus other than the Tintometer and from the use of obsolete specimens. There are now over thirty British Standard Specifications that stipulate colours in terms of Lovibond glasses, especially for many oils and varnishes. In addition, the Ministry of Health specifies Tintometer colours for its milk tests. In America the number of trade and official organisations specifying Tintometer colours or equipment is considerable; these organisations include the American Chemical Society and the U.S. Department of Agriculture. Argentina has an official specification in which vegetable oils are graded according to a method involving the use of Tintometer equipment. These examples—only a few have been given—illustrate how widespread is the use of Lovibond glasses or Tintometer equipment.

Estimating Chemicals by Coloured Reactions

The colour that is measured in a particular test may be that of a transparent material, such as a liquid solution; or it may be that of an opaque object or a piece of paper or textile; or it may be the colour of a powder. All these different sorts of coloured materials can be examined with the Tintometer equipment.

The wide use of a colorimeter in trade and industry derives from the fact that colour tests are widely used in chemistry and in biochemistry. We all remember the red litmus that turned blue when made alkaline. That colour change indicates a change from acidity to alkalinity. There are many such indicators, some of which pass through a range of colours and others pass through varieties of the same hue, as the *p*H changes. Thus the colours can be signs of chemical change, and so the colorimetric value of a solution or suspension can be an indication of the amount or quality of a chemical change. The deepness of colour of a solution is often a sign of the concentration of the dissolved substance. So a colorimetric value can be a measure of concentration. *Purity*, too, is also often indicated by the colour—the word 'purity' here being used to mean the absence of an undesired substance whether in a solution or a mechanical mixture (e.g. face powder) where the tint is sometimes the result of more than one pigment.

Even where there is no significant colour in the substance to be examined, the addition of a chemical reagent can produce a colour indicative of the property being tested. Consider, for instance, cod liver oil. If this is dissolved in chloroform and a small quantity of antimony trichloride is added to the solution, a blue colour develops. The depth of this blue colour measured in terms of the coloured Tintometer glasses is a measure of the quality of the cod liver oil. This is not merely a hypothetical example; it is taken from the Report of the Cod Liver Oil Colour Test Sub-Committee of the Pharmacopoeia Commission.

There are many uses of the colorimeter in everyday affairs. One of the tests is for the rancidity of fat, a test based on the method of Kreis. In this test a red colour is produced after the addition of suitable reagents to the melted fat, but only if there is rancidity, or, in other words, if some of the fat is already oxidised, The degree of redness expressed in Tintometer units is a measure of the amount of rancidity. This test was used, for instance, when a consignment of Polish geese arrived at a port last year for the Christmas market; entirely on the evidence of a colour-matching test, the whole consignment but for six birds was condemned as unfit for human consumption.

Formaldehyde is a chemical that may find its way, in minute quantities, into many preparations, and because it is intensely poisonous a method is needed that can detect traces of formaldehyde. One such test with Tintometer equipment is available. A solution that is contaminated with formaldehyde gives an orange colour when phloroglucinol is added to it, and the depth of the red component of this orange colour provides a measure of the concentration of formaldehyde. This test is extremely sensitive, and can detect formaldehyde when it is present to the extent of as little as two parts in a million in an aqueous solution.

For all colour tests, such as the one for formaldehyde, involving a chemical reaction that yields a coloured compound, it is obviously essential that the conditions under which a particular test is carried out should be carefully standardised. It is necessary, for example, to use a standard solution of the reagent, e.g. the phloroglucinol in the formaldehyde test just mentioned. The depth of the colour produced in the chemical reaction is measured in a specified way: the coloured solution is poured into a standard glass container that enables one to measure the depth of colour in a standard thickness of the solution. (If the test depends on a fugitive colour test, then it is also necessary to stipulate that the colour measurement is to be made at a specified time after the addition of the reagent to the solution under test.)

Colorimetric analysis of this sort is applicable to metallurgy; many a metal can be detected in solution, for example, titanium in sulphuric acid produces an orange colour with hydrogen peroxide, and the yellow component of that orange can be taken as the measure of the titanium concentration. Manganese produces a violet colour in strong acid solution when sodium periodate is added. Copper gives an orange colour, after elaborate treatment to eliminate the colour effect of other metals, when the copper ions meet diethyldithiocarbamic acid. Similarly, iron can be assayed colorimetrically for either ferric iron or total iron. Phosphorus can be estimated colorimetrically using the blue colour that results when ammonium molybdate is added to a solution containing phosphate ions in the presence of stannous chloride.

Applications in Metallurgy and Biology

The use of the colorimeter is not restricted to chemical analysis. Kenneth Williamson, who directs the Fair Isle Bird Observatory in the Shetlands, is using it to record more accurately the colours of bird plumage. Identification and classification of birds depend to a considerable extent on the colours of the feathers, and because of the difficulties of describing colours verbally ornithologists have needed to keep complete skins of many dead birds, so that in doubtful cases the dead specimen can be compared with a type specimen in a museum. Mr. Williamson is now able to avoid the killing of birds by examining the plumage of live birds with a Tintometer colorimeter. The bird is placed in a transparent container and held close to one of the openings at the back of the instrument.

This technique, in which the colour of birds' plumage is measured in terms of the C.I.E. system, has shown that a continental variety of robin exists that can be distinguished from the ordinary English robin because of colour differences in the plumage. Work on the redwing was done in the autumn of 1950 during its migration southwards—the redwing is a winter visitor to England. It was found that the colour-quality of the mantle of the Iceland race of redwings was an aid to identification; for at least one bird, which was considered to have abnormal markings, was proved to have a colour-quality that, when measured and plotted on a graph, was near to the value typical of the Iceland race. This use of colorimetry is still very much in the experimental stage, but it does offer the promise that many biologists may be able to utilise a technique so far restricted mainly to industry and the more quantitative branches of science.

The examples so far described have come from the use of the colorimeter, whether the ordinary model (known as the B.D.H. pattern), or the Lovibond-Schofield model with which the C.I.E. specification can be found. A very great number of colour measurements, however, can be applied with a modified form of the colorimeter. For instance, anyone wanting to measure the amount of haemoglobin in undiluted blood does not need the large colorimeter if he has access to a modified form in which the matching colour has been previously calibrated in terms of haemoglobin concentration. It is the preliminary chemistry and calibration that makes the modified colorimeter so reliable. This modified form is called a *comparator*. A suitable range of Lovibond glasses is inserted in a ring of holes arranged around the rim of a plastic disc. This disc can be rotated so that the glasses are brought, one at a time, in front of the light-source. At the same time the colour being tested is seen alongside the matching colour. To operate the comparator, therefore, all one has to do is to insert the coloured test specimen (this can be in liquid or solid form), and then rotate the disc until a good match is obtained when the instrument is held up to the light. A scale on the instrument then gives the answer in terms of the particular quality that is being investigated.

A comparator of this sort was developed during the war for the use of R.A.F. medical staff who needed a rapid method of deciding what quantity of blood plasma should be given to a wounded airman. It is well known that an extensive burn or wound leads to a condition in which the circulating blood is deficient in plasma. In other words, the blood becomes too thick and does not circulate properly, sometimes causing death. The haemoglobin test already mentioned gives a direct measure of such a plasma-deficiency. But now it is possible for a doctor to take a drop of blood from a casualty, place it in the comparator, get a measure of the plasma needed, transfuse plasma at once, and so increase the victim's chance of life.

The number of such special comparators made by the Tintometer Ltd. is now more than two hundred. Each is the result of much preliminary scientific work. Many of the clinical and analytical uses are of interest only to medical and chemical specialists. Others are interesting to non-specialists as well. For example, there is the estimation of what is called *p*H value, or the concentration of hydrogen ions. This is in fact of importance in many industries and communal affairs, for it is a delicate measure of the acidity or alkalinity. There are indicators that go through changes over a quite small change of *p*H value. These indicators are used in the colorimetric estimate of *p*H value. Bromo-thymol, for instance, is such an indicator. It is full yellow at *p*H 6·0, changing to green at *p*h 7·0 and deep blue at *p*H 7·6. Cresol red is yellow at *p*H 7·2 and purplish red at *p*H 8·8. The Lovibond comparator for *p*H values has discs showing nine steps of colour for any given indicator and is calibrated to read the *p*H value of the colourless liquid being tested with the indicator. A large number of uses of great practical importance follow. For instance, *p*H value is important in bacteriology for the control of media, in boiler water for the prevention of corrosion, in ceramics for the reactions of the clay with agents that produce coagulation of clay particles, in electroplating for the quality of the deposit, in paper manufacture for uniformity in bleaching, in sewage disposal for the speed of digestion, in textile manufacture for the prevention of damage to fibres, and in canning for the sterilisation of food. These are a few examples.

One interesting use of a comparator is apparently far outside the fields of science and industry as normally understood. It is in the field of mental science. Bromide is often prescribed for excitability and sleeplessness. People showing signs of mental disturbance are sometimes calmed down with bromide. But in excess this drug produces intoxication with the accompanying symptoms of apparent mental aberration. It is the opinion of a pathologist who is employed at one of our best-known mental hospitals that people are sometimes admitted to hospital and diagnosed as mentally ill when they are merely overdosed with bromide. If this were to happen there would be a grave error in treatment, not to mention the anguish given to the patient and to relatives. So the Tintometer Ltd. has produced a comparator by means of which a rapid test for the presence of bromide in the blood can be made. In this way one possible source of error in diagnosis can be removed. Thus a simple colour-matching technique becomes a test of great moral, perhaps even legal, importance.

Comparators have been used for the estimation of oxygen in the blood of climbers in a Mt. Everest expedition, for the measurement of phosphate in sea water in the *Challenger* expedition, and for the estimation of carotene in fodder. There are dozens of other uses of comparator or full colorimeter . . . silk grading in Japan and China, the grading of castor oil in Brazil, the grading and matching of face powders in the cosmetics industry, the estimation of mineral excess and deficiency in growing plants (a full technique has been described by members of the Long Ashton Research Station), the routine testing of water supplies, and the grading of salmon in Alaska. There is a Tintometer on every whaling expedition's floating factory. All of these operations depend on the simple visual matching of colours under controlled conditions, and so far the only firm producing a suitably priced colorimeter adaptable to all these needs is the British firm the Tintometer Ltd. In over half a century of development it has established itself all over the world. This is of course due to many factors, but undoubtedly the chief one is the manufacture of graded coloured glasses that are permanent and suitable for a trichomatic control of the matching colour.

This article sums up the series on Russian Science. The four previous articles appeared in our issues for July, August, September and November, and dealt with Russian botany, physics, chemistry and scientific education, respectively. This final article describes the attitude of the Soviet State to science in which it has invested so much in the hope of early dividends from its industrial applications; but the process of forced growth, coupled with the pruning of its natural roots, has led to:

The Dilemma of Soviet Science

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MANY accounts of the organisation, development and achievements of Russian science start with the Revolution, devote much attention to the inspiration of Soviet science by dialectical materialism, and concentrate on the Communist characteristics of Soviet scientific activity. There is a tendency to ignore the fact that Russian science also has roots in Russia's history and in world science. The actual facts will be found to be more illuminating than any mere ideological approach to this subject.

That a great burst of scientific activity followed the Revolution is an incontrovertible fact. The traditional explanation which Communists offer for this is the thesis that the materialist factor of Russia's great need to develop technological industries was the most powerful influence in the stimulating of Russian science and technology. This thesis, temptingly simple and consequently deserving of suspicion, should be considered in the light of the facts.

The two major problems facing the Communist regime in its early days were concerned with food supplies and the resuscitation of Russian industry and transport. Both problems were concerned with the provision of basic necessities, and neither called for the attention of research scientists or technologists expert in the newer technologies. Both problems continued to dominate the scene for several years. When the first phase was over and the interventionist armies had been withdrawn from the frontiers of the new Soviet State, the problem of defence still remained a first priority in the schemes of Soviet economic planners, so that the heavy industries had to cope simultaneously with two enormous needs: they had to equip the expanding Services, and they had to produce the equipment needed for civilian reconstruction.

The fulfilling of the programme of industrialisation depended to a large extent on the importation of capital equipment from abroad. Russia was in a position strongly reminiscent of the times of Peter the Great. He had depended to a large extent on foreign experts and on the importation of manufactured goods. So too did the Soviet rulers. By 1922 Germany had already signed an agreement with Russia providing for mutual economic aid. Large numbers of German engineers and technicians went to Russia to work. The Russian Government organised "Days of German Technique" so that her technologists and scientists could get to know about the latest German developments. Krupps technicians taught the Russians how to make special steels, while diesel engines were manufactured under German supervision in Russia. It was the German aircraft firms like Junkers, Heinkel and Dornier which started aeroplane production in Russia.

America, too, was not slow to renew its trade with Russia, and experts from the U.S.A. were responsible for the design, equipping and bringing into production of many new factories and plants. The development of the big new industrial area in the Urals, which was centred on Sverdlovsk, illustrates the scale of American participation in new industrial enterprises. The huge steel plants of Magnitogorsk, for instance, were designed by U.S. companies. The nearby tractor-producing centre of Chelyabinsk, which has made hundreds of thousands of Forsdon-type tractors, was a mainstay of Russian tank forces during the war. This was the embodiment of the Ford skill and 'know-how' which the Russians bought.

Even the pre-war showpiece, the Dnieperproges Dam, was built by an American engineer, and the five huge turbines which produced the electric power were made in the U.S.A. (Later four similar turbines, but of Soviet manufacture, were added.) American equipment went into new oil refineries, and a significant proportion of the Russians who ran these refineries received their practical training in modern oil technology in the U.S.A. Britain's contribution to the industrialisation of Soviet Russia included such things as machine tools (to the tune of £4½ million), ships' engines, turbines and electrical generators, compressors, presses and other metallurgical equipment, precision instruments and laboratory equipment. The very production of the detailed economic plans of the Soviet bureaucrats would have been impossible without foreign machinery, vast quantities of business machinery being imported, particularly from the U.S.A.

The cost of this imported capital equipment had to be met out of the proceeds of the Russian agricultural effort (including forestry), during that period when agriculture was losing labour to the factories. The implementation of the Soviet plans altogether altered the balance between industry and agriculture; before World War I, agriculture accounted for about 60% of the country's total production as against 40% for industry. (These figures are estimated in terms of the cash value of the products from each sector.) Just before World War II, the relative proportions were 23% and 77%. But it needs to be remembered that Russian agriculture is the real basis of Russia's economic strength, and that the expansion of her industrial sector was paid for by the work of the farmers. It was they who made it possible for the Soviet planners to obtain the foreign equipment which was the basis of the programme of intensive industrialisation.

During this period scientists were not at a premium; it was not men who could make new discoveries who were needed, it was men who could get new factories and new power generators into production and maintain them in production. Experienced technologists and engineers were the men of the moment; they were scarce, and their ranks could not be rapidly reinforced. (Indeed during this period Russia lost a large number of her best technical experts,

as for instance Egloff and Ipatieff from the oil industry, and men like Zworykin.)

Apart from such things as the running of control laboratories in factories, scientists had a comparatively small part to play in this phase when the Soviets were reconstructing and expanding their industries. But the time was coming when Russia's industries would have to be run exclusively by Russian managers, technologists and technicians. In the first phase of industrialisation Russian scientists could most usefully devote their time and energy to preparing the ground for the second phase. There was therefore plenty of work for them to do; they had to organise the university departments, the Polytechnics and the technical schools where the new generation could be trained as scientists, technologists and technicians; they had to complete the training of graduate science students, to make them first-class experts in those branches of science which were gaining importance; they also had the enormous task of planning and organising a network of scientific institutes which could tackle the problems arising in agriculture, industry, in the re-equipping of the Armed Services, in the exploitation of natural resources such as minerals and water-power.

The Academy of Sciences was geared to the machine of government at a very early stage; we find, for instance, that Lenin sketched out a programme of activities for the Academy in 1918, according to which the scientists were to work out detailed plans for the scientific location of industries, the particular purpose of the planning being to reduce the strain on transport—the weakest link in the Russian economy—to the minimum. Lenin also called for scientific advice in connexion with the planners' aim of building an economy that would be self-sufficient in industrial raw materials. The Academy was in fact able to take immediate action with regard to the last-mentioned problem. A number of projects of geographical and geological exploration had been suggested in Tsarist days, but had languished for sheer lack of funds and facilities; under the new government it was possible for the Academy to go ahead with these without further delay. An example is the expedition by the geochemist Academician A. E. Fersman which was sent to the Kola peninsula in the Far North, and which found a vast new deposit of apatite (since exploited as a rich source of phosphate fertiliser). This kind of work was paralleled in the engineering field by the drawing-up of detailed schemes for the development of hydro-electric power.

Applied industrial science was largely the concern of the various commissariats (counterparts of Government Departments in Britain) such as the Commissariat of Heavy Industry and the Commissariat of Light Industry. The first of the two commissariats mentioned controls a number of big research laboratories, and also a chain of Physico-technical Institutes, and an Institute of Chemistry; all these laboratories add up to a research organisation (or 'sector') roughly equivalent to Britain's Department of Scientific Industrial Research. The nucleus from which the chain of Physico-technical institutes grew was the Leningrad Physico-technical Institute, established by Academician Abram Joffe in 1918. Originally this was a small organisation, occupying only a few rooms in the old Polytechnical Institute, and concerned primarily with training physicists. According to J. G. Crowther's account of this establishment (in his book *Soviet Science*), it grew at such a rate that by 1930 it had a staff of 2000—composed of 700 physicists and 1300 assistants; "The policy of centralisation had achieved the aim of creating a nucleus of physicists for the Soviet Union, where previously there had been almost none. But decentralization now became necessary. New institutes were split off, and established in various parts of the country to act as nuclei for still further extension. The institutes of Kharkov, Dniepropetrovsk, Tomsk and Samarkand were founded."

It was not intended in this phase that the Physico-technical Institutes should concern themselves with solving the *ad hoc* scientific problems arising in the factories belonging to the Commissariat of Heavy Industry. These institutes were free to experiment on long-term problems of interest to the Commissariat, and they were the training establishments for the physicists required by the heavy industries. There was freedom, too, to experiment and find the best methods of organising scientific research. 'Centralisation of research' was the fashionable creed when Joffe started the first Physico-technical Institute, a creed which harmonised with the centralised planning of industrial production. In both fields experience proved that early ideas about the relative efficiency of centralisation needed drastic modification. To quote Prof. J. D. Bernal on this point, "In the earlier days in the Soviet Union, when the distinctive characters of scientific research had not been fully realised, giant institutes of up to several hundred workers were formed, but it was soon found in practice that these were difficult to run and very inefficient, and they were broken up into smaller and more manageable units."

J. G. Crowther has described another kind of experiment which Joffe carried out in the early Leningrad days. He believed that it should be possible to train workers to do scientific research without the usual lengthy preliminary training; perhaps there were some with a flair for science who could start research after an abbreviated form of scientific training. Crowther reports (in *Soviet Science*) as follows on the results of this experiment: "Acting on this supposition, about twenty factory workers who had shown definite talent for inventing details in machinery and processes were selected, and set to work in the physical research laboratories. They were given a special course of instruction to acquaint them with the general ideas and objects of the researches to which they were set. The experiment did not succeed. Though every one was a successful inventor, it appeared that none had any special aptitude for scientific research. Joffe said that the men proved to be inventors of machines, and not inventors of ideas, and that the two processes appear to be distinct. Progress in scientific research apparently depends on the invention of scientific ideas, and not directly on the invention of ingenious apparatus. Another interpretation of the result of this experiment is that a mature man cannot be trained to do something else within two years."

The desire for industrial self-sufficiency was paralleled by the Soviet Government's desire that Russia should be self-sufficient in scientific and technological skill. There was a failure to realise, however, that both science and technology owe their progress to the efforts of men of all

nations, and that neither can develop to the full in isolation. Lack of contact with foreign scientists and lack of critical discussion inside Russia did put Soviet scientists at a disadvantage in a way which is made extremely clear in this passage from Vannevar Bush's book, *Modern Arms and Free Men* (London, 1950):

Some twenty years ago a group of Russian scientists headed by Professor Joffe, who was then a great figure in physics, believed that they had made some new discoveries in fundamental theory and practice on insulating materials. After a year or two of reduction to use in a laboratory at Leningrad manned by a highly competent group of young investigators, these discoveries appeared ready to be put to use. They promised on their face to revolutionise electrical insulating materials and hence to be of considerable commercial importance. The Russian government secured patent applications in America and elsewhere, for valid patents could be obtained here by Russia, and still can, for that matter, even though the reciprocal privilege is meaningless. The discovery and invention were announced in lectures here and elsewhere. Industrial groups in this country and Germany were formed to develop the possibilities, and it looked as though the cost of electrical machinery and power might thus be reduced significantly. Great stacks of laboratory records and tests made in Leningrad were made available, experimental work was started, and then after a time it stopped. There was absolutely nothing in the matter whatever; the theory was fallacious, and the insulation prepared in accordance with it simply did not insulate any better than commonly available materials.

Now the point of this story is that there was no intent to deceive on the part of the Russian scientific group. They were completely honest; moreover, they were able men and women, and personally they were likeable and ingenuous, the same sorts of individuals as hard-working, devoted, professional men everywhere. Yet for several years they had followed a false lead, into all sorts of ramifications, without once finding out that the structure they had erected was utterly unsound. This was many years ago; controls have tightened enormously since, and the iron curtain has come down hard. But even at that time this able group was operating in isolation, and its strange adventure was the result of its remoteness from unbiased criticism and of the regimentation of its internal thinking.

We have seen in the case of the Physico-technical Insititutes the scale on which research facilities were expanded. Such expansion was general, and it applied to pure research as much as to applied research. There is the striking example of what happened in the field of agricultural research. To direct research in this sector Lenin appointed N. I. Vavilov, then thirty years old.

Vavilov was a Napoleonic character, being a great organiser as well as a prodigious research worker. Some measure of his organising ability may be gained from the fact that between the years 1921 and 1934 he established no less than 400 research institutes and experiment stations, with staffs totalling 20,000. He concentrated on a programme of stock improvement, which necessitated the collecting of likely species and varieties of economic plants and animals on a vast scale. Thus, for example, he sent out expeditions and succeeded in building up a huge collection of species and varieties of wheat, numbering 26,000 in all, which could be utilised in a breeding programme. He did the same for potatoes, and his work in this connexion was considered so promising that Britain organised a similar collection of potato species and varieties. Out of the investigations Vavilov carried out on his collected plants he was able to arrive at a great and revolutionary generalisation which shed new light on the problem of finding new strains which could be incorporated into schemes of breeding better varieties of economic crops; it was "the principle of diversity", which postulates that the geographical centre of origin of a cultivated plant is located where the genus or species of plant shows the maximum capacity to vary—more briefly, the centre of diversity represents the centre of origin of the plant. (A short account of Vavilov's theory can be found in *Chromosome Atlas of Cultivated Plants, by Darlington and Janaki Amal*; Vavilov's original papers on the subject, translated into English, can be consulted in *The Origin, Variation, Immunity and Breeding of Cultivated Plants*, Selected writings of N. I. Vavilov, published by Chronica Botanica, Waltham, Mass., U.S.A.).

The scientific stations established by Vavilov belonged to the organisation known as the Academy of Agricultural Sciences, which Lenin had planned as a chain of research units to parallel the Soviet Academy of Sciences. The Commissariat of Agriculture, like other commissariats, also carried out some research.

There can be no doubt that the research effort organised by Vavilov was one of the glories of Soviet science. Thus we find it cited by Prof. J. D. Bernal as "a beautiful example of integrated working", which showed how academic and applied science should be co-ordinated (*The Social Function of Science*, 1939, p. 227). Vavilov enjoyed the highest reputation throughout the world, and many foreign scientists made a point of visiting him when they went to Russia. Indeed, a number of foreign scientists actually joined his staff; there was, for example, H. J. Muller, the American biologist who became director of the genetics department in one of Vavilov's research units, the Institute of Applied Botany in Leningrad. During this period Russian genetics was second to none for vigour and originality; it should be noted that under Vavilov other branches of applied botany also flourished, as for example plant physiology.

Judged by any standard, the research organisation created by Vavilov was indeed a mighty empire which opened up new frontiers of knowledge. But it was the kind of empire which must have aroused feelings of jealousy towards Vavilov among many men of lesser scientific ability. One such man was Lysenko. He had made a name for himself at an experiment station at Azerbaidzan with researches into the way in which the rate of maturing of cereals and cotton plants is altered when they are grown at different temperatures. It was this line of research which led him to develop the technique of vernalisation (which is also known as 'yarovisation'), a method of treating seeds or bulbs, for example, so that an earlier crop is obtained. Lysenko's work attracted the attention of Vavilov, and in effect he became one of Vavilov's protégés. With the death of Vavilov at some date between December 1941 and June 1942, Lysenko took charge of all the research stations which his chief had controlled. This fact will be well known

to DISCOVERY readers, who are not likely, however, to be familiar with the steps by which Lysenko climbed to power.

As early as 1932, an All-Union Conference had been called to discuss genetics, and this conference was induced to accept a resolution to the effect that genetics must be made to conform with the creed of dialectical materialism. Two biologists appear to have obeyed this resolution; the first was Krenke, whose work is fairly described by Eric Ashby in his book *Scientist in Russia*; the second was Lysenko. One cannot help wondering which of these two scientists 'planted' the resolution on this, the first of a notorious series of Genetics Conferences. By 1935 Lysenko had gained the support of the Communist Party. His earlier criticisms of classical genetics had been put forward in a moderate and restrained manner, but henceforward his critical approach gave way to a series of polemical attacks couched in dialectical terms and culminating in the personal indictment of a large number of distinguished geneticists. His collaborator was Prezent, a biologist with a flair for presenting biological matters in materialist jargon, and it is no exaggeration to say that much of what Lysenko and Prezent have published under the aegis of the Communist Party has no scientific *meaning* whatsoever, let alone scientific value. That the Party had become their patrons became clear in 1935; in that year they became joint editors of a new journal, *Yarovizatsia*, and they published their 'theories' in book form, and only through political influence could they have obtained the printing facilities necessary for those two enterprises. By 1937 the time was ripe for another Genetics Conference, which was staged with all the theatrical efficiency of a purge trial; Lysenko appeared as chief prosecutor, and he and his supporters denounced Vavilov for alleged failure to get improved crops by the application of genetical methods and for wasting time on the collection of breeding material. (Previously the latter point had been used as pro-Soviet ammunition, for it demonstrated, they said, how much more scientific Russian methods were and how much more valuable the results would be than those obtained by foreign capitalist seed merchants.) The next scene in the tragic farce was a further Genetics Congress in 1939, at which Lysenko argued that 'Mendelian-Morganism*'—his term for classical genetics—was synonymous with Fascist race-theories. Classical genetics was now branded with official disfavour; it was bad because it had clerical roots in Mendelism and foreign roots in its more modern aspects. What the propagandists needed was a genetical theory with strong *Russian* roots, and so there came to be invented *Michurinism*, named after the plant breeder Michurin.

Lysenko was now firmly in the saddle, and in 1948 he brought his campaign to an end. As head of the Academy of Agricultural Sciences, he read a report to a conference which he convened in the summer of 1948. In it he stated that "The Central Committee of the Party examined my report and approved it." The words had an ominous ring for the twelve scientists he denounced in that report, and immediately afterwards all twelve were removed from their posts. That Lysenko had influence outside the Academy of Agricultural Sciences was proved by the fact that one of the scientists deposed was the secretary of the Biological Division of the Soviet Academy of Sciences itself.

* T. H. Morgan had been elected an honorary member of the Soviet Academy of Sciences in 1932.

It may be argued that the Lysenko affair is not so serious as it appears; this argument admits that the intrusion of politics into science is bad when carried to such lengths as in the genetics controversy, but then proceeds to give a comforting assurance that the genetics controversy is altogether exceptional, and that other branches of science are unsullied by political interference. This does not seem to tally with the facts, however; for instance, in 1947 several distinguished economists were denounced for their 'un-Marxist' approach; Lysenko's campaign involved the disgracing of scientists other than geneticists, and it led to the dismissal of at least three medical scientists; criticism has begun in the lay press of Russian physicists who publish their results abroad, and who support the 'idealistic' theories of foreign scientists such as Bohr and Heisenberg; in chemistry there have been similar developments, Linus Pauling being cited as a typical example of a foreign scientist whose theories are anti-Marxist; several historians and institutes of historical research are also under a cloud.

Soviet scientists would probably find little difficulty in coping with dialectical materialism if it could be treated as a philosophical doctrine, which could be applied, if it shed new light on a particular scientific problem, or ignored if it did not apply.

But it is not merely a philosophical doctrine; it sets the political scene, and when it is translated into terms of political action it can do little else but harm in the scientific world. At best it seems to have produced few positive results, very few discoveries having arisen from the application of this philosophy to scientific problems; it has on the other hand produced some disastrous results, as one has seen in the Lysenko affair which cost some twenty scientists their jobs. If scientists have to concentrate their attention on the ever-veering 'Party line', as some have done in order to gain promotion, then their scientific research suffers. Political patronage is always fickle, and the scientist who builds his career on political influence can win only an ephemeral reputation either as a scientist or as a politician. The most successful Russian scientists appear to be the ones who have least to do with the Communist Party; the highest administrative posts may be beyond their grasp, but at least they can devote nearly all their time to scientific work.

What is more serious to the Soviet scientists of today is the official xenophobia which cuts the international contacts so indispensable to the continuance of scientific progress. At the end of the last war there were great hopes that the barriers separating Russian scientists from their friends abroad would begin to disappear. When the Academy of Sciences celebrated its 220th anniversary in 1945, it was possible for the president, the late S. I. Vavilov, to speak freely of the links which Russian science had with the science of Britain, the U.S.A., France, and so on; he presented a picture in which Russian science was a part of the body of international science. At about this time, too, the Commissar for Higher Education told Eric Ashby of plans to exchange university textbooks with foreign universities, and gave "the impression that he would encourage the interchange of students between Russia and other countries". Yet by March 1948 Kaftanov, the

Commissar for Higher Education whom Ashby quotes, was condemning international scientific organisations as "foreign political organisations designed to serve imperialist interests". In *Pravda* (March 3, 1948), Kaftanov wrote:

Behind the pompous, demagogic phrases of reactionary politicians, particularly American and British, about world science and about the establishment of a world organisation for scientific research, is concealed the desire to subordinate development and achievements of world science to imperialist interests.

The Party line had clearly veered once more; the Russian scientists knew that henceforth their only contacts with the outside world would be the foreign scientific and technical journals selected and distributed inside Russia by the authorities.

The dissolution of the links between Russia and the rest of the world which had developed during the war was accompanied by a campaign, started by the Press and the radio, but extended to the schools, to convince the public, and the younger generation in particular, that Russia had invented more machines and made more discoveries than any other country. In a short time the propaganda machine had claimed the credit for a huge number of inventions; Russia, it was claimed, had first invented everything from the steam engine to penicillin, including the radio, aeroplane, submarine, diesel engine, the telegraph, jet propulsion, long-range rockets, the caterpillar tractor and atomic energy.

Behind this campaign stood the newly created "All-Union Society for the Dissemination of Political and Scientific Knowledge". Started in July 1947, it was designed to harness for political purposes the talents of the intelligentsia, and to help in arousing "Socialist consciousness in the masses". It was to popularise the achievements of Russian science and technology, and to counteract "all anti-scientific views and remnants of alien ideology". With such objectives to determine its agenda, it is scarcely surprising that the board of this society is chiefly remarkable for its lack of scientific representatives.

In the earliest days of the Soviet regime, the target had been economic self-sufficiency. There were abundant raw materials, and here at least there was agreement between the Russian government, Russian experts and foreign experts; in most materials, including strategic and critical raw materials, Russia could be virtually self-sufficient if technology could be brought to bear on the problems of exploitation and production. Doubtless the authorities hoped to be self-sufficient by now in the human skills required in an industrial programme designed so that Russian factories and farms could produce everything that the country needs. It is doubtful whether Russian scientists and technologists can fulfil their share of the programme, and one cannot avoid thinking that there is a hint of 'whistling to keep one's courage up' behind the campaign of claiming that all the great inventions of history were made in Russia. One can assume that the campaign was launched for reasons of pure expediency; Russia needs to be self-sufficient in the field of invention and technological development, and this propaganda appears to be based on the tenet that repetition of the claim of inventive self-sufficiency will eventually lead to the desired result. The campaign may be acceptable to a propaganda expert, but the inconsistencies arising from its manipulation of facts may arouse in Russia a desire to get at the truth which could lead to unintended results. One point which is very obvious is that one immediate reaction will be the asking of this question: if invention flourished so exceedingly under Tsarist regimes (and most of the inventions claimed antedate 1917), does the Soviet regime really promote invention? In the realms of radio and electrical development, the campaign has brought to the attention of the public such facts as these: the carbon rod lamp of Lodygin (1872) and the Jablochkoff candle (1878) were among the first successful electric lamps; the first boat to be powered by electricity was the one which von Jacobi drove along the river at St. Petersburg in 1838; then there was the pioneer work of Lenz (1804–65) of St. Petersburg University, and A. S. Popov (1860–1906) of the Kronstadt Torpedo School. Where (the Russian people will ask) are the Soviet counterparts of the Tsarist inventors and discoverers? The men who work in the electric power stations cannot fail to recall that the regime relied on foreign equipment when it embarked on the great hydro-electric schemes, and that foreign experts were brought in to install that equipment and get the plants into operation.

The scientists and technologists who know the history of science and technology cannot be other than dismayed at the isolationist trend, which could only be tenable if self-sufficiency in the technological industries had already been achieved. An introvert policy of isolationism is itself no sign of strength, but rather the reverse; the fact of isolation will not help Soviet science and technology, for a country which suppresses the very heterodoxy without which science cannot thrive intensifies, by its very pursuit of orthodoxy, the need to import criticisms by foreign experts against which the findings of its own scientists can be tested.

Nationalist traditions make up only a part of the cultural heritage on which scientific and technological activity is founded. A Soviet scientist is not just a Soviet citizen who has made science his career; he has strong roots in Russian history and in international history, and neither can be ignored if his talents are to be fully developed. The great names of Russian science are those of men who had excellent contacts with the outside world. Under the Tsars, the Russian scientists were not forbidden to travel abroad, and the Soviets used to allow, up till about 1933, both scientists and technologists to improve their skill and knowledge by foreign study.

If the Soviet authorities now believe that Russia should be completely self-contained, because her scientists and technical experts are (or should be) by this time completely trained and can usefully occupy the whole of their time working on the problems that are at hand inside the frontiers of Russia, it means that they fail to understand the true character of science and technology.

In the days when skilled tradesmen were the most important men in technical production, a country with sufficient supplies of raw materials could be both isolated and self-sufficient. With the development of the extreme specialisation, which is characteristic of our age, this is no longer feasible; today it is possible to find many branches of science and technology in which only a few men throughout the whole world can be described as 'expert'. Russian specialists working in such sectors are in

fact wasted if they are forced to work in isolation without access to the complementary foreign specialists. To the Russian government it may not matter that this isolation reduces the benefit to the world of such work; it should be concerned, however, with the fact that this isolation also reduces the benefit of such work to *Russia*.

A factor which further aggravates the position of the Soviet specialist is the change in the official attitude towards 'official secrets'. Within this category come many facts which in Britain, for instance, would not rank as 'official secrets' at all. Indeed it must now be difficult for any Russian scientist to know when a fact is an 'official secret'.

In connexion with the extravagances of Soviet Russian official secrecy, I would refer readers to pp. 283–6 of Bedell Smith's *Moscow Mission: 1946–1949*, in which can be found full details of the sad aftermath of an inquiry which the U.S. Embassy in Moscow made about a serum which showed promise in cancer research. Briefly, the only result was the trial and conviction of the secretary of the Soviet Academy of Medical Sciences for prematurely revealing secrets of Soviet science. (And this occurred at about the same time as the Russian government sent abroad samples of the much-vaunted Bogomolets serum so that foreign experts could test it.)

In the years before 1930 such isolationism and secrecy were understandable, for counter-revolution was a danger against which the authorities had to be prepared. But over all the years that the Soviets have been in power the scientists and technologists have exhibited no inclination towards 'treasonable' or 'deviationist' activities. In the years around 1930 a few scientists were dismissed for suspected counter-revolutionary activities, but the twenty years that followed have earned them the right to be trusted, and the right to work without political interference. But since 1945 there has been more political interference than at any previous time in Soviet history. Is it because the authorities are beginning to doubt the truth of their dogma that "New developments in science do not undermine materialism, but on the contrary adduce new data confirming the scientific nature of Dialectical Materialism. Only on the basis of Dialectical Materialism can science develop further" (*Large Soviet Encyclopaedia*, 1938; article on 'Materialism'). Perhaps science is undermining belief in such dogmata, whereas the authorities would have preferred scientific thinking to have been affected by the materialist creed.

Consistency in the official attitude can, however, really be found if one assumes that the authorities consider the international position of Russia to be similar to that in 1920–30, when everything was subordinated to defence considerations. If that is the explanation, then the character of the conflict between the State and the Communist Party, on the one hand, and the Soviet scientific world on the other, suggests that the authorities consider the country to be relatively weaker than it was during the period 1920–30. It suggests, too, that the policy of making Russia self-sufficient on the scientific and technological fronts has not so far been successful.

Technical miracles were what the early Soviet leaders expected science to be able to produce. One recalls Lenin's faith in the miracle-working powers of electrification, which were to transform the Soviet economy; one recalls the way he expected underground gasification to supersede more conventional ways of winning coal. It seems, too, that genetics was expected to make good in a short time the huge exports of agricultural products sent abroad to pay for the capital equipment which alone made such schemes as large-scale electrification feasible. The planners certainly left the scientists with plenty of scope to expand the Russian research effort, and to develop the training facilities needed to educate the next generation of scientists, technologists and technicians. One can find almost unlimited quantities of statistics to demonstrate the grand scale of such expansion. One can quote, for example, the figures showing the research effort organised directly by the Academy of Sciences: when the Soviets took over, there were only 45 Academicians, the Academy controlled only one single research institute, and its total scientific staff numbered only 109. By contrast, in 1946, the Academy of Sciences comprised some 150 scientific institutions, including 53 research institutes, 16 independent laboratories, 6 observatories, 35 stations and 15 museums —apart from the branches and the independent Academies. There are 144 full Academicians and 201 corresponding members.

Similar expansion is shown by comparison of 1917 figures and current figures for the number of science graduates produced each year in the universities and technical training establishments.

The figures are impressive, but how effective is the whole of this scientific effort? Technologically Russia appears to have a long way to go, if one examines statistics for industrial production in the context of Russia's huge labour force and the size of her reserves of raw materials. (A useful compilation of such figures, shown in comparison with statistics for the other great nations, can be found in such books as Hanson Baldwin's *The Price of Power*.) No convenient index of Russia's scientific strength exists and, indeed, any assessment is made particularly difficult as one cannot begin to evaluate the quality of Russian researches when the results of so much work are kept secret and never published; an added difficulty arises from the fact that Soviet scientists are not allowed by their government to be considered for Nobel Prizes, so that one cannot use the number of Nobel Prizes awarded to Soviet scientists in a particular period as an index of Russia's scientific progress.

The only thing that is obvious is that the Soviet authorities expected more of their scientists and technologists than was within the powers of mere humans to deliver. History should have taught them that science and technology will not act like some magic box which will disclose miracles capable of satisfying all material needs at the wave of a Marxist wand. Only when Soviet scientists and technologists are allowed to work under the kind of conditions which encourage them to their best efforts will the activities of the specialists match up to the expectations of the politicians. Those optimum conditions are likely to be found to be very different from those under which they are expected to work today, and the Russian authorities will have to learn from experience what those conditions are.

The Bookshelf

A Century of Science. Edited by Prof. Herbert Dingle.

A Century of Technology. Edited by Dr. Percy Dunsheath.

(These companion volumes are published by Hutchinson's Scientific and Technical Publications, London, 1951; the price of each volume is 15*s*.)

BY-PRODUCT of the Festival of Britain has been a spate of topical historical books. These two volumes were among them, but both are worth a permanent place in any well-equipped library, where they may be found valuable for reference purposes, while any reasonably well-educated person interested in getting a well-rounded bird's-eye view of the progress of science and technology during the last century will find them easy reading and informative. They will appeal to a readership extending far beyond the ranks of professional scientists and technologists; the specialist will find them useful because they provide a convenient survey of advances made in fields outside his own particular specialism.

A Century of Science has seventeen authors, and eighteen writers have contributed to the other volume. They have done a good job in assimilating the large amount of detail which has to be taken into account when one attempts to evaluate the significance of developments that occurred during a century of rapid progress, and they have also succeeded in assessing the most important trends of the period under review. It is interesting to compare the two volumes, and to discover that the technologists have been more successful than the scientists in writing up their particular specialisms in such a way that the chapters can be read by the non-professional person as well as by the professional scientist or technologist. One feels that, as a general rule, the scientist author was too conscious of the expert and critical reader peeping over his shoulder the whole time he was writing his chapters, with the result that he has had less success in catering for the non-expert than happened in the case of *A Century of Technology*. This is presumably symptomatic of the growing trend whereby, outside the pages of the specialist books and journals, the story of scientific progress is being recorded less effectively than is the story of technological progress. This may prove a serious matter in the future, for it would indeed be a disaster if pure science should fail in competition with technology to attract a fair proportion of the possible new recruits to its ranks.

The Rose in Britain. By N. P. Harvey. (London, Plant Protection Ltd., 1951; distributed by Simpkin Marshall; 181 pp., 17*s*. 6*d*.)

THIS BOOK has all the qualities of the good scientific textbook, for it is systematic, comprehensive, accurate, and as up to date as possible. Another point in its favour, and one which will recommend it to DISCOVERY readers, is that *it explains the reasons behind technique* (e.g. in the section on pruning), whereas so many gardening books are unsatisfactory to the scientifically minded because they provide dogma without explanation, and give descriptions of rule-of-thumb cultural methods which may or may not be effective, and which can only be tested by experiment—a wasteful process with roses in particular, in view of the myriad experiments which have been carried out since the rose first came into cultivation several thousand years ago. This excellent monograph contains everything the gardener needs to know about rose cultivation, including the control of insect and fungal pests, and also propagation by layering, cuttings and budding. There is a very useful glossary of species and varieties, giving synonyms, diagnostic characters such as flower colour and fragrance (and sometimes habit of growth), country of origin, name of raiser and the year the variety was introduced. Selected lists of roses most suitable for various purposes fill nine pages of the book. Old-fashioned roses such as centifolias and damasks are omitted because they constitute a special field on their own.

A special feature of the book is the coloured illustrations. Twenty-two varieties are figured in full-page plates, which were produced by letterpress and attain an extremely high standard of colour reproduction from colour photographs.

Four Thousand Million Mouths. By F. Le Gros Clark & N. W. Pirie. (London, Geoffrey Cumberlege, Oxford University Press, 1951, 222 pp., 22*s*. 6*d*.).

PROF. S. C. HARLAND's chapter from this book was published in the October 1951 issue of DISCOVERY, under the title of "Genetics and the World's Food." We recommend to it readers as the most comprehensive scientific document dealing with the problem of providing food for the rapidly increasing world population which has been put before the public.

The authors of the other chapters are F. Le Gros Clark, G. V. Jacks, F. C. Bawden, H. D. Kay, John Hammond, C. E. Lucas, G. A. Reay, C. L. Cutting, N. W. Pirie, A. L. Bacharach and T. Crosbie-Walsh, editor of *Food Manufacture*. The book is good value for money. Its low price indicates that a large number of copies have been printed, and we feel sure that the publishers will find their belief in the book justified by the demand for it. People have been discussing for a long time the Malthusian situation which has arisen because the world population has multiplied too fast, with the result that ever increasing numbers of people live on the edge of starvation. Many of those who have entered this controversy have lacked the information necessary to an intelligent discussion of the subject. This information must be brought into the controversy if it is to reach any conclusions capable of providing a basis for decisive action. This book supplies just that kind of information which was so badly needed

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Night Sky in December

The Moon.—Full moon occurs on Dec. 13d 09h 30m, U.T., and new moon on Dec. 28d 11h 43m. The following conjunctions with the moon take place:

December.

7d 10h	Jupiter in conjunction with the moon		Jupiter	4° S.
22d 23h	Saturn	,,	Saturn	6° N.
23d 03h	Mars	,,	Mars	6° N.
25d 14h	Venus	,,	Venus	8° N.
27d 06h	Mercury	,,	Mercury	8° N.

In addition to these conjunctions with the moon, Mars is in conjunction with Saturn on Dec. 19d 13h, Mars being 0·7° S.

The Planets.—Mercury sets nearly an hour after the sun at the beginning of the month but later draws closer to the sun and is in inferior conjunction on Dec. 17. After this it becomes a morning star and rises about 2h before the sun at the end of December. Venus is a morning star, rising at 3h 20m, 3h 55m, and 4h 35m, on Dec. 1, 15, and 31, respectively. The stellar magnitude varies from −3·9 to −3·6, and the visible portion of the illuminated disk from 0·58 to 0·70. Notice under 'Conjunctions' that Venus is close to the moon in the afternoon of Dec. 25. Mars rises at 1h 40m, 0h 50m, and 23h 50m, at the beginning, middle, and end of the month, respectively, and can be seen in the constellation Virgo, close to η Virginis in the early part of the month. Jupiter, visible in the earlier part of the night, sets at 1h 40m, 0h 50m, and 23h 50m, on Dec. 1, 15, and 31, respectively. The planet can be easily identified as it is a conspicuous object, and if there should be any doubt about it, notice that it is due south at 19h 40m on Dec. 1 and 4 minutes earlier each succeeding night. Saturn, a morning star, rises at 2h 25m, 1h 40m, and 0h 40m, on Dec. 1, 15, and 31, respectively. It draws closer to θ Virginis and at the end of the month is a little NW. of this star. The planet is close to Mars on Dec. 19 and of course this proximity is obvious a night or two before and after this date.

During the first week of December meteors may be observed emanating from the constellation Gemini and if their paths are traced backwards they will be seen to converge towards θ Geminorum. Those who possess a small telescope should try it on α Geminorum (Castor) and they may be able to see its companion quite close to it. This is one of the finest of the double stars in the northern hemisphere.

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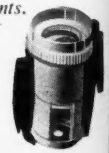

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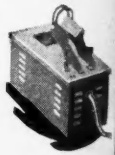

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